Traverse Environmental

Water quality in the mid Taiari/Taieri River catchment

A summary of monitoring activities and findings

Prepared for: Upper Taieri Wai

October 2024

Water quality in the mid Taiari/Taieri River catchment: A summary of monitoring activities and findings

Prepared for:	Upper Taieri Wai
Prepared by:	Juliet Milne
Date of issue:	11 June 2024 (original) Re-issued 31 October 2024 with minor updates and revisions

Quality Assurance		
Reviewed by:	Laura Keenen	
Approved for release by:	Dr Olivier Ausseil	
Report status:	Final	

Disclaimer: This report has been prepared for the sole use of our client, for the particular brief and on the terms and conditions agreed with our client. It may not be used or relied on (in whole or part) by anyone else, or for any other purpose or in any other contexts, without our prior written agreement.

Cover photo: Taieri River at Hyde-Macraes Road (J. Milne).

Recommended citation: Milne J. (2024) Water quality in the mid Taiari/Taieri River catchment: A summary of monitoring activities and findings. Report prepared for the Upper Taieri Wai by Traverse Environmental. 41 p.

Executive summary

The Taiari/Taieri (Taieri) River is the fourth longest river in New Zealand and has significant natural, ecological, recreational and cultural values. The Upper Taieri Wai, a community-led catchment group dedicated to resource management issues in the upper Taieri catchment, is both overseeing and supporting activities to understand and enhance water quality throughout the entire Taieri catchment, including through the Healthy Taieri Integrated Farm Planning (IFP) project. Although the IFP project operates catchment-wide, separate reports have been prepared for each of the upper, mid and lower Taieri plain communities to provide a focus on water quality at a more localised scale. This report addresses the mid Taieri catchment, incorporating the area between Tiroiti in the north and Outram Glen in the south.

This report:

- outlines details of current and historical water quality monitoring carried out by the Otago Regional Council (ORC) and several other organisations to date,
- summarises what we know about water quality state and trends from monitoring and investigations, drawing on existing readily available reports and data, and
- identifies water quality issues and associated information gaps and monitoring priorities.

A detailed summary of each of these topics is included within the body of the report.

Monitoring activities and information

A reasonable amount of information exists on physical, chemical and microbiological aspects of water quality in the mid Taieri catchment but information on ecological and physical habitat components of river health is more limited. The ORC currently has six surface water and one groundwater quality state of the environment (SOE) monitoring sites and has monitored additional stream sites intermittently in the past. Recent additions to the SOE surface water quality monitoring programme include periphyton (algae) biomass (2019–2022 only), high frequency logging of dissolved oxygen levels in the Taieri River at Sutton and Outram, and monitoring of invertebrate community health and physical stream habitat quality at all wadeable sites. River level/flow monitoring is carried out at four sites on the mainstem of the river and four tributary sites, while rainfall is measured at five locations. The Dunedin City Council also carries out water quality monitoring in the catchment associated with the Middlemarch Wastewater Treatment Plant discharge (into an old oxbow of the Taieri River) and raw water sourced from Deep Stream and Deep Creek for Dunedin City's drinking water supply.

Other organisations that have collected significant amounts of information on river and stream health in the mid Taieri catchment include the University of Otago (e.g., in the Sutton Stream area) and the Department of Conservation (e.g., as part of its Te Mana o Taiari project). In addition, in February 2023 the Mid Taieri Wai carried out ecological assessments at six stream sites.

Current state and trends in water quality

Based on recent ORC state assessments (mostly spanning 2017–2022) and the results of other monitoring and investigations carried out over the last five or so years, water quality in the mid Taieri River catchment is 'good'. Both the Taieri River and its tributaries are characterised by low concentrations of plant-available forms of nitrogen relative to median concentrations reported in other rural areas of New Zealand. Median plant-available phosphorus concentrations are also lower in the Taieri River mainstem at Sutton and Outram than upstream at Tiroiti and Waipiata. In addition, the sites at Sutton and Outram record better (i.e., higher) dissolved oxygen levels and fewer occasions of elevated water temperatures than at Waipiata. Median nutrient concentrations in the shallow groundwater north of Middlemarch are higher than those recorded at surface water sites but they are not high when compared to national benchmarks for groundwater quality.

In contrast with nutrients, both turbidity and faecal contamination are higher in the Taieri River at Sutton than at Tiroiti and Outram. Both the mainstem site and Sutton Stream at SH 87 are assigned to Band D of the National Policy Statement for Freshwater Management (NPS-FM) for *E. coli*, with Sutton Stream recording more than a third of test results above 260 *E. coli*/100mL (the amber/alert level of the national microbiological

water quality guidelines, a level above which there is deemed an increased risk of infection from exposure to pathogens). Faecal contamination does not appear to be limited to wet weather or high river flow events, suggesting that stock access and birdlife are contributing factors at times, particularly in summer. Observations from Mid Taieri Wai monitoring and the report author support this view.

The ORC does not currently monitor any sites on any tributaries of the Taieri between Tiroiti and Sutton and an investigation of water quality and ecology across a few of these may be worthwhile, particularly given the deterioration in visual water clarity and increase in *E. coli* between these mainstem sites.

The ORC's most recent trend assessments indicate several aspects of water quality in the mid Taieri catchment improved over the 10-year period ending June 2022, with turbidity and concentrations of phosphorus decreasing across all sites. However, there was also evidence of increasing plant-available nitrate-N concentrations in the Taieri River at Tiroiti and in the shallow groundwater at a site monitored near Middlemarch. The reasons for the observed trends are unclear but the Taieri River appears to be nitrogen-limited so an increase in nitrogen would likely stimulate nuisance aquatic plant growth more than additional phosphorus would.

Information gaps and monitoring considerations

Visual clarity (the suspended fine sediment attribute in the NPS-FM) is currently estimated by the ORC from turbidity measurements using a national equation. This equation was not intended to apply to naturally tannin-stained waters such as the Taieri River and contributes to the mainstem sites being classified in a degraded state (Band D) under the NPS-FM. Visual clarity measurements are needed for a meaningful assessment of the suspended fine sediment attribute. Nonetheless, turbidity is already high at Tiroiti relative to further upstream and is higher again at Sutton. It would be useful to investigate contributing sediment sources.

Long-term ecological and physical stream habitat quality data are lacking for the mid Taieri catchment. Little is known about periphyton biomass other than the Taieri mainstem sites at Sutton and Outram appear to experience periodic nuisance periphyton growth. Macroinvertebrate community health is 'fair', likely falling into Band C of the NPS-FM, consistent with all mainstem sites in the upper Taieri catchment. Recent data for the ORC's other SOE sites indicates that invertebrate communities are in better condition in Sutton Stream and Deep Stream but poor in the Nenthorn Stream at Mount Stoker. Mid Taieri Wai's ecological assessments also identified degraded invertebrate communities in several streams, including Sheepwash Creek. These assessments identified a lack of riparian vegetation and sedimentation of the stream bed as having the biggest impact on stream health. A lack of flow in summer is likely also a major contributor.

Collection of information on subcatchment-scale land use and land management practices such as irrigation, stocking, fertiliser and riparian management practices, would be useful to help understand the drivers and direction of water quality trends in the mid Taieri. This will be particularly important should proposals to increase the area of irrigated land in the Strath Taieri go ahead.

Monitoring-related suggestions include:

- carrying out more comprehensive assessments of periphyton and fine deposited sediment cover at all SOE sites in the mid Taieri,
- ensuring rapid assessments of physical habitat quality are carried out annually at all SOE sites when macroinvertebrate samples are collected,
- investigating the source of faecal contamination and potential sediment-related issues in the Sutton area, and
- establishing a site-specific relationship between turbidity and visual clarity for the naturally tannin-influenced SOE sites to inform assessments of the suspended fine sediment attribute under the NPS-FM and enable a meaningful catchment-specific target attribute state to be set.

Contents

Executive summary 3

1 Introduction 7

1.1 Report purpose and scope 7
1.2 Limitations 7

2 Mid Taieri catchment 8

2.1 Climate 9
2.2 Hydrology 9
2.3 Land cover, soils, land use and irrigation 9
2.4 Aquatic ecological and recreational values 10

3 Water quality monitoring – who has done and is doing what? 11

3.1 Otago Regional Council 11
3.2 NIWA 15
3.3 Dunedin City Council 15
3.4 University of Otago 16
3.5 Department of Conservation 17
3.6 Mid Taieri Wai 17
3.7 Summary 18

4 Current state – what we know 19

4.1 Recent ORC State of the Enviroment (SOE) reporting 19
4.2 Insights from other recent monitoring and investigations 25
4.3 Summary 27

5 Trends – is water quality getting better or worse? 29

5.1 Surface water quality 30
5.2 Groundwater quality 30
5.3 What might be behind the trends? 31

5.4 Summary 31

6 Issues, gaps and priorities 32

6.1 Sediment 32

6.2 Nutrients 33

6.3 *E. coli* 34

36

6.4 Gaps and priorities 36

Acknowledgements 38

References 39

1 Introduction

The Taiari/Taieri (Taieri)[1] River is the fourth longest river in New Zealand and has significant natural, ecological, recreational and cultural values. The river's headwaters originate in the Lammermoor and Lammerlaw Ranges in inland Otago. The river flows through three plains – the Upper Taieri, Strath Taieri, and Lower Taieri – enroute to the sea 30 km south of Dunedin. The Otago Regional Council (ORC) carries out water quality monitoring within each of the plains as part of its statutory role in managing river health. In recent years, consistent with a nationwide trend, landowners and catchment-based groups have also carried out monitoring, helping to fill important gaps in understanding of river health.

This report was prepared for the Upper Taieri Wai to support the activities of the Healthy Taieri Integrated Farm Planning (IFP) project. Water quality is one of three major focal points for the project. Although the IFP project operates catchment-wide, separate reports have been prepared for each of the upper, mid and lower Taieri plain communities to provide a focus on water quality at a more localised scale. For the purposes of this report, the mid Taieri catchment incorporates the area from Tiroiti, north of Hyde, down to SH 87 at Outram.

1.1 Report purpose and scope

The primary aim of this report is to collate what has been done and is known about water quality in the mid Taieri catchment to inform freshwater farm plan development associated with the Taieri IFP project and other activities, such as potential future community-based monitoring and restoration. Specifically, the report:

- outlines details of current and historical water quality monitoring carried out by different organisations,
- summarises what we know about water quality state and trends, based on existing readily available reports and data, and
- identifies water quality issues and associated information gaps and monitoring priorities.

A series of ArcGIS layers have been provided with the report containing the key details of surface water quality monitoring and investigation sites, as well as groundwater quality, river level/flow and rainfall monitoring sites. These layers also include monitoring sites across the upper and lower Taieri; separate reports, similar in format to this one, have been prepared for those areas (see Milne & Rados 2024, Milne 2024).

1.2 Limitations

This report has relied heavily on existing reports and collated or summarised data from third parties. Incomplete details, conflicting information and errors were followed up where possible, but it was beyond the scope of this project to re-examine data sets. Additional analyses of already reported data were also out of scope but some further analysis was done to help illustrate or understand particular issues.

Although water quality information associated with university research projects and resource consents is summarised, the search was not exhaustive and it is likely that additional information exists to that captured here.

[1] The Taiari River is the correct Māori name for the Taieri River, but this is still in the early stages of adoption within the catchment. To avoid potential confusion with the names of long-established monitoring sites, the more widely known spelling of Taieri is used in this report except where the correct spelling forms part of an entity or project name.

2 Mid Taieri catchment

The mid Taieri catchment lies mostly within the jurisdiction of Dunedin City, bordered by the Rock and Pillar Range on the west and the Taieri Range on the east. Tiroiti, located between the small townships of Kokonga and Hyde, marks the transition between the upper and mid (or Strath) Taieri plains. The Taieri River flows south through the middle of the plain towards Middlemarch, after which the largest of its many tributaries enter, including Sheepwash Creek, and the Nenthorn, Sutton, Deep and Lee streams (Figure 2-1). The river then flows through the Taieri Gorge before exiting onto the Lower Taieri Plain at Outram.

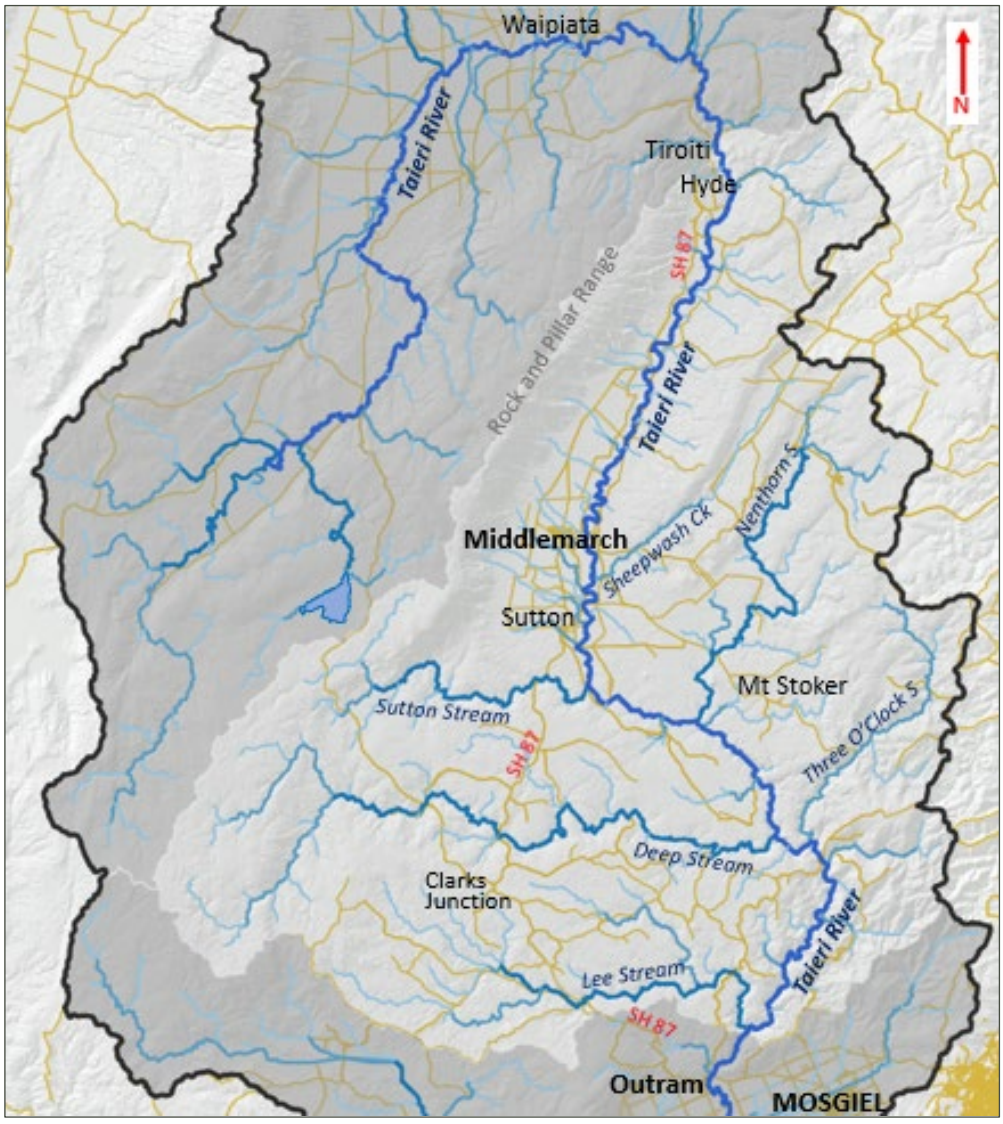

Figure 2-1: The mid Taieri catchment and some of the key locations and tributaries referred to in this report. Tiroiti marks the upstream boundary of the catchment discussed in this report and Outram Glen marks the downstream boundary. The central basin in the area, incorporating Middlemarch township, is known as the Strath Taieri.

Several reports describe the topography, soils, vegetation, land-use, climate, hydrology and the natural, ecological, recreational and cultural values of the Taieri River catchment (e.g., Ryder & Tocher 2020, Levy et al. 2021). However, compared with the upper and lower Taieri catchment areas, considerably less information is documented on many of these aspects for the mid Taieri. Unless indicated otherwise, the following points are drawn from Levy et al. (2021) and NIWA's weather and climate summary for Otago (Macara 2015) to provide some context for understanding water quality in the mid Taieri catchment.

2.1 Climate

- The mid Taieri is characterised by hot summers and cold winters. Maximum temperatures of 25-30ºC are common in summer and subzero minimum temperatures occur for 90 days per year, on average. The hottest and coldest temperatures recorded at Middlemarch between 1981 and 2010 were 36ºC and -11.7ºC.
- Average annual rainfall at Middlemarch is 495 mm. Rainfall is typically highest in December and January, accounting for 26% of the annual rainfall. On average, there are only 80 days a year when greater than 1 mm of rainfall is recorded. In contrast, the Rock and Pillar Range has much higher annual rainfall (around 1,800 mm).
- Summit Rock in the Rock and Pillar Range marks the highest elevation in the catchment (1,450 m above sea level), with the range regularly snowcapped for several weeks on end during winter.

2.2 Hydrology

- Flows in the mid-reaches of the Taieri River are generally lowest towards the end of summer and highest during snowmelt in spring.
- Numerous streams, including the Cap Burn and Lug Creek, flow off the western flanks of the Rock and Pillar Range and across the basin into the Taieri River. Many of these streams draining the range provide an important water source when the valley floor is dry. Some of these streams lose flow to alluvial soils before reaching the river.
- The Strath Taieri basin is thought to contain a single unconfined aquifer that consists primarily of silty gravel. It also contains iron pans and silt lenses that form perched water tables, locally confined aquifer conditions, and channels of preferential groundwater flow. The water table is shallow (less than 5 m below ground level) across much of the valley, but is deeper to the west and beneath localised pockets of silt.
- Similar to that of the upper Taieri, the Strath Taieri groundwater system receives direct rainfall recharge that is supplemented by leakage from streams around the basin's edges. Groundwater generally flows to the east/southeast, parallel to the direction of surface water, before discharging into the Taieri River. The groundwater-surface water interaction has implications for water abstraction because surface water is fully allocated in the area (ORC 2006).

2.3 Land cover, soils, land use and irrigation

- The mid Taieri catchment comprises tussock grasslands, farmland and wetlands. Some tussock areas lie within public conservation land, including the headwaters of Deep Stream, the source of 80% of Dunedin City's drinking water (Ryder & Tocher 2020).
- Recent (yellow), pallic and gley soils are the main soil orders on the plain. Within these, there are 11 different soil types, of which Pigburn, Middlemarch and Komako make up 75% of the land area (Chrystal & O'Neill 2018).
- Land use is dominated by low intensity mixed sheep and beef farming, interspersed with small areas of deer farming. There is also some exotic forestry in the southernmost area of the catchment (around Mt Allan).
- Based on data from 2017, the bulk of the catchment is dryland pasture, with minimal irrigation (13% of land area or 1,464 ha, Figure 2-2). Irrigation water is sourced from the Taieri River and its tributaries and reliability is estimated to be 60% or lower. There is a proposal to increase the reliability of irrigation water supply, and potentially more than double the current area under irrigation (Chrystal & O'Neill 2018).

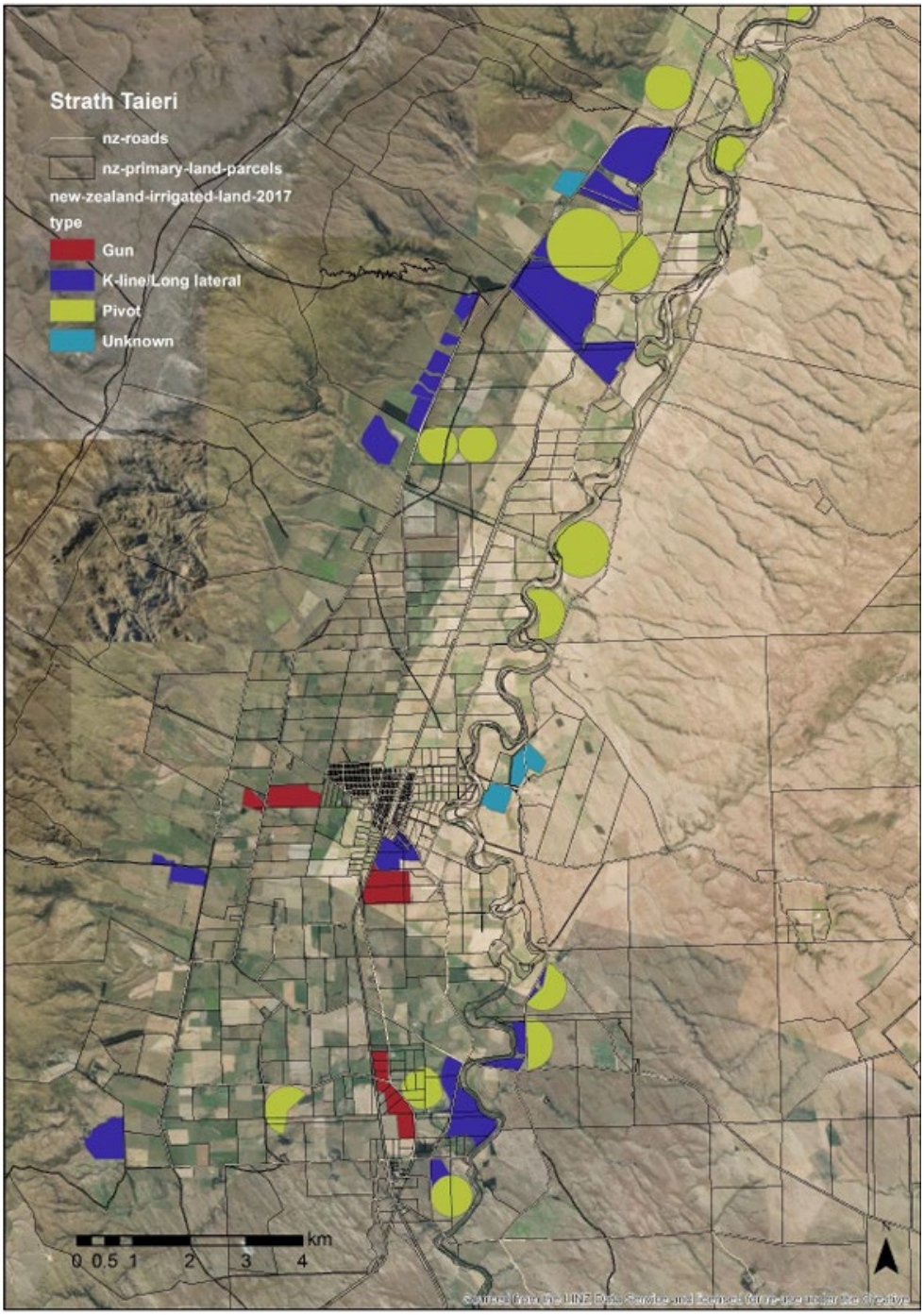

Figure 2-2: Irrigation areas and (known) types in the Strath Taieri in 2017. Reproduced from Appendix 2 of Chrystal and O'Neill (2018).

2.4 Aquatic ecological and recreational values

- The mid Taieri catchment supports eight regionally significant wetlands, including the Sutton Salt Lake, New Zealand's only inland salt lake.
- Various native fish are found in the mid Taieri catchment, which is recognised in the Regional Plan: Water for Otago as providing significant habitat for Flathead and Lower Taieri galaxiids, koaro and lamprey. There is also a significant presence of eel, salmon and brown trout (Ryder & Tocher 2020).
- Taieri River swimming spots include Moonlight Bridge, Sutton and Outram Glen.

3 Water quality monitoring – who has done and is doing what?

The ORC carries out the most water quality monitoring in the mid Taieri. A few other organisations have also collected data on a one-off, short-term or ongoing basis to meet resource consent requirements or support research initiatives. This section presents a summary of the readily available monitoring and investigation activities carried out to date, with a focus on what each organisation has monitored, where and when. Collating a record of monitoring activities in the catchment provides an important first step in identifying gaps in understanding and priorities for future monitoring.

Water quality and ecosystem health

Water quality includes physical, chemical and biological characteristics. Water quality in rivers, streams and groundwater is usually described and assessed in terms of its suitability to support particular uses or values, such as recreation, ecosystem health, drinking and food gathering.

Good water quality is important for supporting healthy freshwater ecosystems but is only one of five components of river health defined under the National Policy Statement for Freshwater Management (NPS-FM) 2020. The other components are *aquatic life* (e.g., plants, macroinvertebrates, fish), *habitat* (e.g., the composition of the riverbed, shade), *ecosystem processes* (e.g., nutrient cycling) and *water quantity* (e.g., flows).

Although water quality is the focus of this report, current and historical monitoring activities are summarised across all five components of river health. Soil quality monitoring is also summarised because of the known linkages between soil health and water quality.

3.1 Otago Regional Council

The ORC carries out routine State of the Environment (SOE) monitoring in the mid Taieri catchment and recreational water quality monitoring at Outram Glen on the boundary of the mid and lower Taieri catchments. On occasion the ORC also carries out one-off or short-term investigations targeting specific water quality issues or information gaps. Only one specific investigation was identified for the mid Taieri.

3.1.1 State of the Environment monitoring

A primary goal of SOE water quality monitoring is to track changes in water quality over time. This requires consistency in monitoring site locations, indicators and methods. In reality, sites, indicators and methods do change, primarily as a result of reviewing the cost and value of the information gained from monitoring, the emergence of new national legislation (e.g., the NPS-FM 2020), environmental pressures, and developments in monitoring practices (e.g., National Environmental Monitoring Standards) and technology.

Surface water quality and ecology

The ORC has four SOE monitoring sites in the mid Taieri catchment, as well as a site on the main stem of the Taieri River at the northern-most boundary (Tiroiti) and a site on the southernmost boundary at Outram Glen. These mid-catchment sites are the Taieri River at Sutton, Nenthorn Stream at Mt Stoker, Sutton Stream at SH 87 and Deep Stream at SH 87 (Figure 3-1, Table 3-1). In the past, SOE monitoring was also carried out near the bottom of Sheepwash Creek, Three O'Clock Stream and Lee Stream on an intermittent basis (Table 3-1).

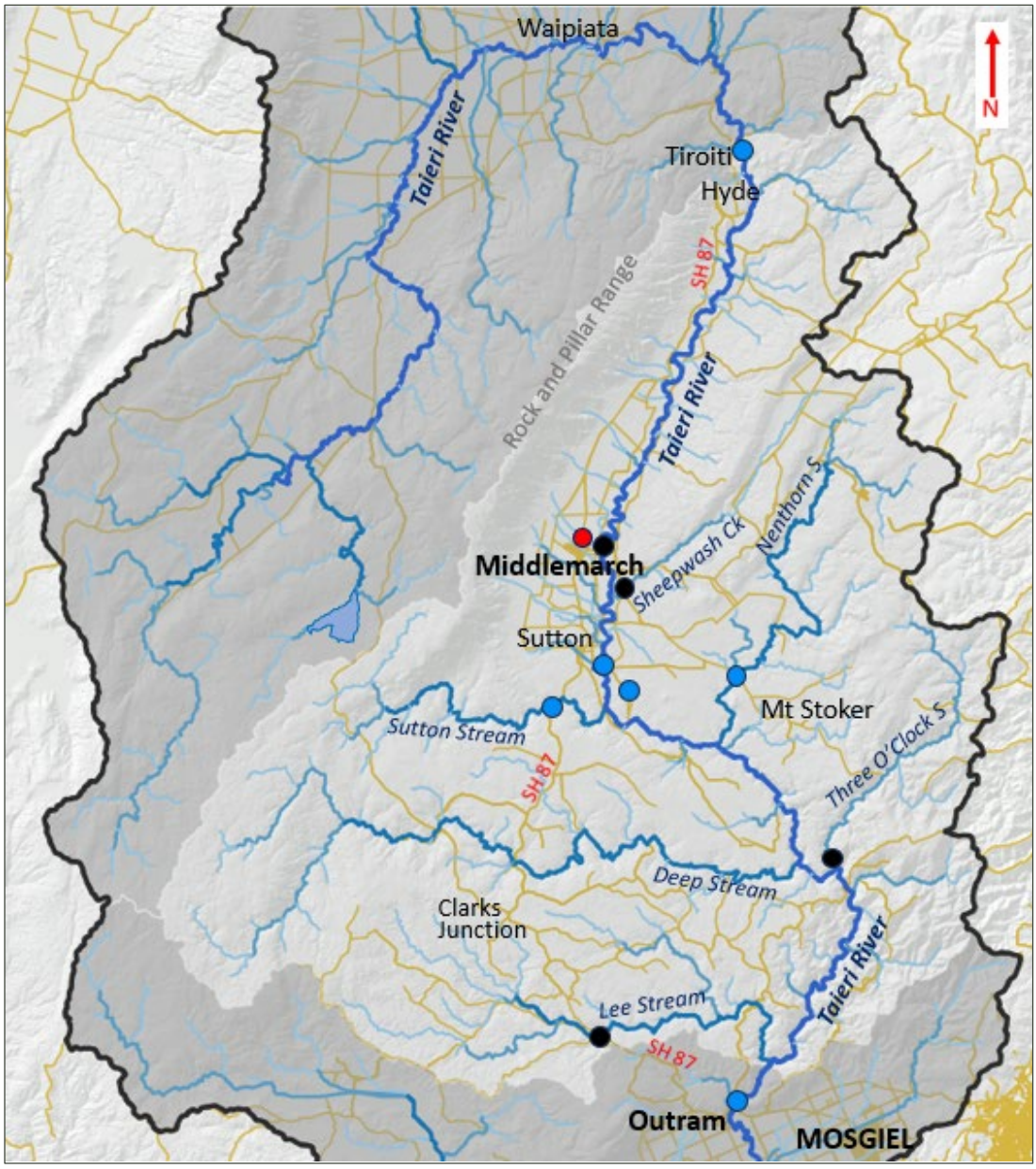

Figure 3-1: ORC SOE surface and groundwater quality monitoring sites in the mid Taieri catchment. The blue and black circles indicate current and historic surface water quality monitoring sites, respectively. Flow and rainfall are also monitored at some of these sites. The red circle indicates the location of the only groundwater SOE monitoring well.

The Taieri River at Outram has the longest monitoring record, dating back to April 1983, with several other sites dating from the early 1990s. However, there have been breaks in the monitoring record at these sites (e.g., Outram was not monitored between November 2006 and April 2014 – although it was monitored by NIWA during this period). Monitoring of the Taieri River at Sutton has taken place since August 2006.

At each SOE site, water samples are collected monthly[2] and measured for water temperature, pH, turbidity and concentrations of dissolved oxygen (DO), conductivity, plant-available nutrients (ammoniacal nitrogen, nitrate-nitrite nitrogen (NNN) and dissolved reactive phosphorus (DRP)), total nitrogen (TN), total phosphorus (TP) and *E. coli* indicator bacteria. This measurement suite is similar to that adopted by most regional councils, the main difference being that most councils also routinely measure visual clarity (as discussed later in this report, the ORC estimates this from turbidity measurements).

[2] Prior to mid-2014, water sampling was two-monthly and, in some years, samples were only collected on five occasions.

Table 3-1: Summary of ORC's surface water quality monitoring and investigations in the mid Taieri catchment. More details of the monitoring and investigations are available as ArcGIS layers.

Programme and rationale	Monitoring focus	Where and when
SOE river water quality programme State and trends in river health (ongoing programme)	**Water quality:** Water temperature, pH, turbidity and concentrations of dissolved oxygen, conductivity, ammoniacal nitrogen, nitrate-nitrite nitrogen, total nitrogen (TN), dissolved reactive phosphorus (DRP), total phosphorus (TP) and *E. coli* indicator bacteria. Also periphyton biomass and ecosystem metabolism at two sites and, more recently, macroinvertebrates and physical habitat quality at all wadeable sites.	Six current sites – includes monthly water quality sampling and, more recently, annual macroinvertebrate sampling at wadeable sites: • Taieri R at Tiroiti – routinely (for water quality) since May 2014 • Taieri R at Sutton – since Aug 2006 • Sutton Stream at SH 87 – since Nov 2017 • Nenthorn Stream at Mt Stoker – since Jul 2014 • Deep Stream at SH 87 – since Jul 2013 • Taieri R at Outram – Apr 1983–Oct 2006, then since May 2014 Some earlier data exist for most of these sites; three sites were originally monitored on an intermittent basis every few years and three were originally monitored by NIWA (see section 3.2). The Taieri River at Sutton site replaced the original mainstem site located at Cottesbrook Bridge (Moonlight Road); the ORC's records for this site are missing but based on ORC (2006a, b), it appears to have been routinely monitored between 1997 and mid-2006. Three other historical SOE sites monitored on an intermittent basis were: • Sheepwash Creek at Mt Stoker (1999–2012) • Three O'Clock Stream at Hindon (1998–2018) • Lee Stream at SH87 (1999–2014)
2010—11 investigation Initiated in response to SOE monitoring results indicating signs of degrading trends in water quality in the Taieri River at Tiroiti and Sutton	SOE water quality suite and a one-off ecological assessment of tributary sites for macroinvertebrate diversity, fish, abundance and condition, and streambed condition in terms of deposited fine sediment cover and depth (including particle size and shuffle index measurements). See Kitto (2012).	12-month investigation between Sept 2010 and Sept 2011 incorporating 18 sites across the upper and part of the mid catchment reaches, including: • sites on the Taieri mainstem at Tiroiti and Sutton, and • sites on the upper and lower reaches of Lug Creek.

Once a year during stable river flows in late summer/early autumn, the riverbed invertebrate community (e.g., insects, snails and worms) is also sampled. It appears that sampling was originally limited to the Taieri River at Sutton, but the ORC expanded its biological monitoring programme a few years ago and there are now several sets of macroinvertebrate data for each of Sutton Stream at SH 87, Nenthorn Stream at Mt Stoker, and Deep Stream at SH 87. Rapid assessments are also made of physical habitat quality (e.g., bank stability, riparian vegetation, shade) at wadeable sites. In addition, on the mainstem at Sutton and Outram:

- water temperature has been monitored at high frequency (every 5-15 minutes) since February 1999,
- DO has been monitored at high frequency since late October 2020, and
- the amount of riverbed periphyton (algae) was assessed monthly – when river flows allowed – as chlorophyll *a* biomass (from rock scrapings) between July 2019 and September 2022.

The periphyton and DO monitoring additions were made in response to requirements of the NPS-FM 2020 and provide additional information on the ecological health of the river. Both water temperature and DO vary across the day and seasonally, so high frequency monitoring is needed to capture the extreme lows and highs that can influence river and stream health. These measurements are also needed to calculate ecosystem metabolism, an indicator of energy producing and consuming processes in rivers and an attribute regional councils must monitor under the NPS-FM 2020.

The ORC does not carry out any routine fish monitoring in the mid Taieri catchment at present.

Groundwater quality

Monitoring of groundwater quality is carried out in one well in the shallow unconfined aquifer (H43/0132, 9.1 m deep) near Middlemarch (Figure 3-1). Based on the ORC's Environmental Portal data, routine sampling in this well began in September 2008. At this time, water samples were collected twice a year and tested for a typical groundwater SOE water quality suite, including ammoniacal nitrogen, nitrate nitrogen, DRP, trace elements (e.g., calcium, magnesium) and *E. coli* bacteria. The frequency of water quality sampling increased to quarterly intervals from around mid-2011 in line with monitoring of other SOE groundwater wells across the Otago region. The static water level in the well is also measured quarterly (prior to water sample collection).

River flow/level and rainfall

Based on the ORC's Environmental Data Portal, river flow and/or water level monitoring is currently carried out at four mainstem and five tributary sites. From north to south, these sites and the monitoring start date are:

- Taieri River at Tiroiti (May 1982)
- Taieri River at Sutton (August 1960)
- Sutton Stream at SH 87 (July 1986)
- Nenthorn at Mt Stoker Road (November 1982)
- Deep Stream at SH 87 (April 1992)
- Three O'Clock Stream at Lamb Hill (May 2010)
- Taieri River at Hindon (July 2020)
- Lee Stream at SH 87 – 1 km downstream (January 2018)
- Taieri River at Outram (April 1968).

Some of these sites provide important flood warning information for the lower Taieri Plain; while high river flows in the upper Taieri catchment can take several days to reach Outram, high flows arising from rainfall in subcatchments such as Three O'Clock and Deep Stream can reach the lower catchment in a matter of hours (O'Sullivan et al. 2013).

The ORC currently operates four rainfall monitoring stations in the catchment. Two of these are located at existing SOE water quality monitoring sites, Nenthorn at Mt Stoker Road and Deep Stream at SH 87, and have records dating back to August 1993. The other sites are located at Three O-Clock Stream at Lamb Hill (monitored since September 2009) and in the Rock and Pillar Range northwest of Middlemarch (since September 2023).

Soil quality

Soil quality is a relatively new addition to SOE monitoring in Otago and is based around a subset of sites on different land uses that are monitored at different frequencies. To date, one monitoring site in the Strath Taieri has been sampled (once, in March 2022), located on sheep and beef farmland in Middlemarch. Soil properties tested include soil acidity (pH), nutrient and organic carbon content, and two indicators of soil compaction (bulk density and macroporosity).

3.1.2 Recreational water quality monitoring

During December to February each year, the Taieri River at Outram is monitored at approximately weekly intervals for *E. coli* as part of the ORC's summer recreational water quality programme. This monitoring is additional to the SOE monitoring carried out at this site. All *E. coli* test results are reported on the Land Air Water Aotearoa (LAWA) website. Additional 'follow-up' testing is usually carried out when a routine sample result exceeds 260 *E. coli*/100mL, the amber/alert level of the MfE/MoH (2003) national microbiological water quality guidelines. At this level, there is an elevated (but still acceptable) risk of infection from contact recreation. Any result exceeding the red/action level of 540 *E. coli*/100 mL[3] is deemed to pose an unacceptable health risk.

3.1.3 Targeted investigations

The only known water quality investigation carried out by the ORC to date is the 2010–11 investigation reported by Kitto (2012). This investigation focused primarily on the upper Taieri catchment (14 sites) but included the Taieri River SOE sites at Tiroiti and Sutton as well as paired sites on Lug Creek above and below farmland (refer Table 3-1). The rationale for including Lug Creek was not stated but it is one of the larger tributaries draining the eastern flanks of the Rock and Pillar Range and provides the only known water quality data for this part of the catchment.

3.2 NIWA

The National Institute of Water and Atmospheric Research (NIWA) once monitored water quality monthly at three sites of relevance to the mid Taieri catchment as part of its National River Water Quality Monitoring Network:

- Taieri River at Tiroiti – between January 1989 and January 2016,
- Sutton Stream at SH 87 – between January 1989 and October 2018, and
- Taieri River at Outram – between January 1989 and January 2016.

Water samples were tested for a similar range of variables to the ORC's SOE programme but, unlike the ORC (and most long-term council programmes), consistency in laboratory provider and test methods was able to be maintained for the majority of the near 30-year monitoring record. The water quality monitoring was complemented with monthly assessments of periphyton cover and annual macroinvertebrate sample collection.

NIWA monitors rainfall at its weather station at Middlemarch, with records dating back to August 2000.

3.3 Dunedin City Council

The Dunedin City Council (DCC) carries out water quality monitoring in March Creek and the Taieri River near Middlemarch as part of resource consent requirements associated with the discharge from the Middlemarch wastewater treatment plant (WWTP). Treated wastewater is discharged to a dry oxbow bed of the Taieri River downstream of the confluence with March Creek. The discharge infiltrates into the ground but can also flow into the Taieri River via the oxbow (Black 2021). It is assumed that flows to the Taieri River are limited to very wet conditions.

There have been changes in what is monitored and when over time reflecting changes in WWTP operation and consent requirements. The current consent, granted in January 2022 for a term of seven years, requires testing of treated wastewater and the Taieri River upstream and downstream of the discharge four times a

[3] The MfE/MoH (2003) guidelines specify a red/action level of 550 *E. coli*/100mL but this became 540 when *E. coli* was included as a human health attribute for primary contact recreation in the NPS-FM.

year for 5-day biochemical oxygen demand, total suspended solids, ammoniacal nitrogen, DRP, pH and faecal coliform indicator bacteria. In 2020, as part of the application for the current resource consent, more intensive sampling was carried out involving monthly sampling at five surface water sites and three rounds of sampling of four shallow groundwater wells in the vicinity of the WWTP (Figure 3-2). These samples were tested for concentrations of suspended solids, *E. coli* and various forms of nutrients.

Figure 3-2: DCC surface (blue circles) and ground water (red circles) quality investigation sites associated with the Middlemarch Wastewater Treatment Plant. These sites incorporated an unnamed water race/drain adjacent to the treatment ponds, shallow groundwater wells and the mainstem of the Taieri River. The sites were sampled intensively for a short period in 2020.

The DCC also monitors the quality of the water sourced from the upper reaches of Deep Stream and one of its tributaries, Deep Creek that form part of Dunedin City's potable water supply.[4] The monitoring frequency and water quality variables tested are based on the (minimum) requirements for networked drinking water supplies set out by Taumata Arowai (2022). Current monitoring is based around:

- continuous monitoring of conductivity, pH and turbidity (i.e., using installed sensors),
- fortnightly monitoring of *E. coli* and nitrate-N,
- monthly monitoring of iron, manganese and colour, and
- six-monthly monitoring of total concentrations of heavy metals.

3.4 University of Otago

The University of Otago has carried out research throughout most of the Taieri catchment. One study that included many stream sites within the mid Taieri was an investigation by Townsend et al. (1997a) of the relationship between land use and stream conditions on stream macroinvertebrate communities. This study involved the collection of a range of physical, chemical, food web-related and invertebrate data from 54 stream sites across the Taieri catchment, including two sites on each of Nenthorn, Sutton, Three O'Clock, Big and Lee

[4] Sites in the lower Taieri catchment are also monitored as raw source water supplies to Dunedin City – see Milne (2024) for details.

streams. A related piece of research involving these same sites looked at the effects of streambed disturbances on aquatic macroinvertebrate communities (Townsend et al. 1997b).

Other examples of research involving stream water quality and ecological data collection in the mid Taieri catchment include:

- assessments of changes in the condition of Lake Mahinerangi and major tributaries between the 1960s and 1980s as agricultural development in the catchment increased (e.g., Malthus & Mitchell 1988),
- an assessment of seasonal variation in the ecological community structure and food web attributes of grassland streams – involving collection of nutrient, periphyton, invertebrate, crayfish and fish data at sites on Sutton Stream and a tributary of Three O'Clock Stream (Thompson & Townsend 1999), and
- investigations into the effects of agricultural development of native tussock grassland catchments on stream ecosystems in tributaries of Deep Stream (Riley et al. 2003).

3.5 Department of Conservation

The Department of Conservation (DOC) has carried out fish surveys in various streams across the mid Taieri catchment as part of its freshwater conservation mandate. In the last few years, there has been more intensive ecological monitoring through Te Mana o Taiari, a project within Ngā Awa, a whole of catchment ('mountains to the sea') river restoration programme launched by DOC in 2019. This has included the use of eDNA testing across multiple tributaries of the Taieri River to complement existing fish monitoring methods. Surveys in 2023/24 were expected to incorporate assessments of water and sediment quality on eight waterways in the mid Taieri:

- Sheepwash Creek
- Deighton Creek
- Deep Creek (tributary)
- Deep Stream (tributary)
- Three O'Clock Stream
- Game Cock Creek
- Lee Stream
- Taieri River upstream of Lee Stream confluence.

Kai Tahu is a partner in the catchment-wide project and has been involved in the monitoring, including completion of cultural health assessments.

As part of Te Mana o Taiari, DOC has also commissioned comprehensive assessments of the predicted impacts of climate change on aquatic and terrestrial ecosystems in the Taieri catchment. Predicted changes in rainfall and river flows have been assessed as part of this. These assessments are reported in Goldsmith (2023) and Closs et al. (2024).

3.6 Mid Taieri Wai

In February 2023, the Mid Taieri Wai Community Catchment Group, supported by a freshwater scientist from Waterscape Connections, carried out a one-off survey of stream health at six sites in the mid Taieri. Three sites were located near Middlemarch (Deadbullock, March and Sheepwash creeks) and two were in the Lee Stream subcatchment (Canton and Fortification streams). The remaining site was an un-named tributary of Deep Steam. The sites were selected to give a good representation of the area in terms of land use and other features (Dale 2023).

The surveys incorporated components of NIWA's Stream Health Monitoring and Assessment Kit (SHMAK), including water temperature, conductivity, visual clarity, periphyton, macrophytes, macroinvertebrates, and

physical habitat quality. An assessment of streambed sedimentation was also carried out and water samples were collected for environmental DNA (eDNA) to identify the range of different aquatic (and terrestrial) organisms present. An additional water sample for eDNA analysis was collected from the upper reaches of the Deep Stream catchment (Dale 2023).

3.7 Summary

- The ORC currently has six surface water quality SOE monitoring sites within the mid Taieri catchment and has monitored additional sites intermittently in the past. Two of the current sites – Taieri River at Tiroiti and Sutton Stream at SH 87 – were picked up from NIWA when it began closing some of its National River Water Quality Monitoring Network sites from 2014 onwards, ending a near 30-year uninterrupted monitoring record of water quality and macroinvertebrates. Surface water sample tests include nutrients, turbidity and *E. coli*. In addition, both water temperature and dissolved oxygen are measured at high frequency in the Taieri River at both Sutton and Outram.
- Annual monitoring of macroinvertebrate and habitat quality was introduced across all of ORC's SOE sites a few years ago and periphyton biomass monitoring was carried out monthly at the Taieri River at both Sutton and Outram between mid-2019 and mid-2022.
- *E. coli* testing is carried out on the Taieri River at Outram weekly over the summer months as part of the ORC's regional recreational water quality monitoring programme.
- The only known targeted investigation of water quality was carried out in 2010–11 (Kitto 2012). This investigation was primarily focused on the upper Taieri catchment but also included monitoring of water quality and ecological variables at four sites in the mid Taieri catchment.
- One shallow groundwater well has been monitored since 2008 as part of the ORC's SOE groundwater quality monitoring programme. Concentrations of nutrients, metals and *E. coli* are some of the variables tested (four times a year).
- River level/flow monitoring is carried out at eight sites across the mid Taieri, including four sites on the mainstem of the river and four tributary sites. The site with the longest record is the Taieri River at Sutton (since August 1960). Five other sites have at least a 30-year record.
- The ORC currently operates four rainfall monitoring stations, with the longest records dating back to August 1993 (Nenthorn and Deep Stream at SH 87). Rainfall is also monitored by NIWA at their weather station in Middlemarch.
- The ORC recently established a soil quality monitoring site on a drystock farm near Middlemarch that has been sampled once to date for various properties, including pH, nutrient and organic carbon content, and indicators of soil compaction.
- The DCC monitors water quality in the Taieri River four times a year as a requirement of its resource consent for the discharge of treated wastewater from the Middlemarch Wastewater Treatment Plant into an old oxbow of the Taieri River. It also monitors water quality in the upper reaches of Deep Stream and in Deep Creek.
- The University of Otago collected water quality and ecological data across multiple streams sites as part of various research projects in the 1990–2000s.
- Both DOC and the Mid Taieri Wai have completed ecological surveys at different stream locations in the mid Taieri catchment over the last few years. These surveys included some one-off water quality and sediment sampling.

4 Current state – what we know

In this section we summarise what is known about the current condition (state) of water quality in the mid Taieri catchment. We use recently reported information from ORC's routine surface water quality monitoring sites and high-frequency water temperature and dissolved oxygen monitoring results for the Taieri River at Sutton and Outram. Because of the interactions between surface and ground water, we also consider the ORC's most recent assessment of groundwater quality and the results of soil quality testing. We then look at the results of other monitoring and investigations.

Note: Recreational water quality monitoring results for the Taieri River at Outram are summarised in a companion report for the lower Taieri River catchment (Milne 2024).

4.1 Recent ORC State of the Enviroment (SOE) reporting

4.1.1 Surface water quality

The most recent assessment of surface water quality state in the mid Taieri catchment was carried out as part of an Otago-wide assessment of river, lake and groundwater quality prepared by Ozanne et al. (2023). The assessment of state used data collected during the five-year period from July 2017 to June 2022. The primary focus of the river and lake components of the report was SOE variables that are mandatory ecosystem health attributes under the NPS-FM 2020. Consequently, not all of the available data were examined and the current state assessment only classified or graded each attribute into NPS-FM bands of A to D (or A to E in the case of *E. coli*). Where readily available, the results of other recent state assessments (e.g., ORC 2021, LAWA) are drawn on to fill in some of these gaps.

What is an attribute and what do Bands A to E mean?

An attribute is a specific term used in the NPS-FM 2020. It refers to a measurable characteristic, such as the concentration of nitrate nitrogen, that is used to assess how well a certain freshwater value (e.g., ecosystem health, recreation) is provided for within a river or lake. Attribute state is generally:

- calculated from regular measurements over a fixed time period (e.g., as a median of monthly measurements over five years), and
- expressed as one of four or five numerically defined bands (A to D or A to E).

In many cases, the NPS-FM specifies a minimum acceptable state (or national bottom line) for an attribute. Councils must monitor and regularly assess current attribute states to track progress towards meeting the future target states established with community input. Target states must be set to maintain or improve river health from a baseline state that was established at a set time (typically 2017).

Attribute bands can be thought of as a bit like a report card where A is the highest and D/E the lowest. However, a lower grade for a particular attribute does not always mean a river is in poor health. A river's natural characteristics, such as the brown tannin staining in Taieri River due to local geology, mean Band A may be an unrealistic and unnecessary target, even in near pristine headwaters. In this section, attribute states of band C or lower are identified to flag potential issues that are then revisited in Section 6.

Not all variables monitored in SOE programmes and investigations are NPS-FM attributes (e.g., water temperature, stream habitat). However, national guidelines can be used to assess these variables.

The ORC's 2017–2022 state assessment (Table 4-1) found water quality across all six SOE river or stream sites was 'very good' in terms of low potential for ammoniacal or nitrate nitrogen toxicity (Band A). However:

- suspended fine sediment (visual water clarity) for the Taieri River at Tiroiti, Sutton and Outram was graded Band D, and
- *E. coli* in the Taieri River at Sutton and Sutton Stream at SH 87 was graded Band D.

Table 4-1: Summary of overall* NPS-FM 2020 attribute grades assigned to ORC SOE sites in the mid Taieri catchment. Summarised from Ozanne et al. (2023) but with the Outram site grade for suspended fine sediment (estimated from measurements of turbidity) adjusted from C to D to align with the site's correct NPS-FM sediment class classification.

Site	Ammonia toxicity	Nitrate toxicity	DRP	Suspended fine sediment	*E. coli*
Taieri R at Tiroiti	A	A	C	D	A
Taieri R at Sutton	A	A	B	D	D
Sutton S at SH 87	A	A	A	A	D
Nenthorn S at Mt Stoker	A	A	A	A	A
Deep S at SH 87	A	A	A	A	A
Taieri R at Outram	A	A	B	D	B

* For many NPS-FM attributes, more than one metric (e.g., median, 95th percentile) is graded but the metric with the lowest grade determines the overall attribute grade.

Toxicity versus other effects

Bands A to D of the NPS-FM for ammoniacal nitrogen and nitrate nitrogen only relate to *toxic effects* on aquatic life. As such, the band thresholds are set at very high concentrations relative to the median concentrations reported for the majority of rivers in New Zealand (which commonly fall into band A or B). However, adverse effects on river ecosystems can occur at much lower nitrogen concentrations through stimulating nuisance growth of periphyton (algae) and macrophytes (aquatic plants). Eutrophication can significantly affect stream life, including through depletion of water column oxygen levels when algae/plants die and break down.

Whether nuisance periphyton or plant growth occurs is dependent not only on nutrient concentrations but other factors such as water temperature, shading, and the frequency of river flows of a sufficient magnitude to 'flush' the riverbed clean. Some guidance has been developed by MfE (2020, 2022) to provide a starting point for deriving nutrient concentrations for managing periphyton biomass, as required by the NPS-FM. The 2020 guidance was used in ORC (2021) to estimate river trophic state in Otago in the absence of any significant periphyton biomass monitoring data.

The D grading for suspended fine sediment is based on a conversion of turbidity measurements to visual clarity and comparison against NPS-FM attribute bands. However, as will be addressed in Section 6, this conversion is problematic for naturally tannin-stained waters.

Although the Taieri River at Tiroiti was graded Band C for plant available (i.e., dissolved reactive) phosphorus or DRP), Tiroiti marks the upstream boundary of the mid Taieri and the median DRP concentration was lower downstream at Sutton and Outram. Differences in water quality between these three mainstem sites can be seen more clearly by comparing median turbidity and median nutrient concentrations at each site over the five-year period ending June 2022. This comparison is shown in Figure 4-1 alongside the median values for all other Taieri River mainstem sites monitored over the same period. The comparison indicates that:

- median concentrations of nitrate-N were similar between Tiroiti and Sutton, but higher at Outram,
- median concentrations of DRP progressively decreased between Tiroiti and Outram,
- the median turbidity value at Sutton was the worst across all Taieri River mainstem sites other than at Allanton on the lower Taieri plain, and
- the median *E. coli* count was higher at Sutton than Tiroiti and Outram, and the same as that at Waipiata.

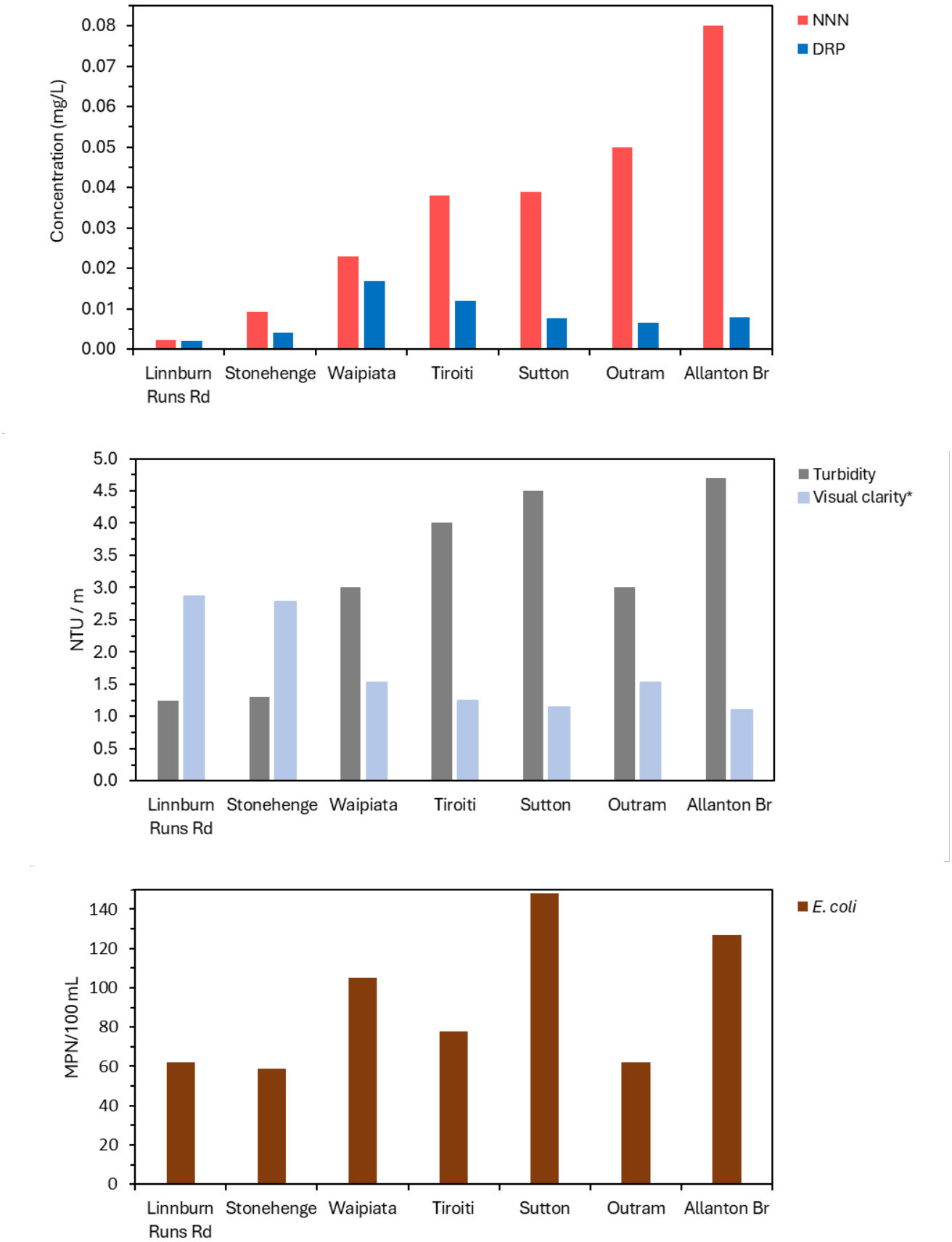

Figure 4-1: Median nutrient, turbidity, visual clarity* and *E. coli* values across all Taieri River SOE water quality monitoring sites. Based on the results of monthly sampling between July 2017 and June 2022, reported in Appendix 1 of Ozanne et al. (2023).

* Visual clarity estimated from turbidity measurements using a national equation.

Overall, plant-available forms of nitrogen (i.e., ammoniacal nitrogen and nitrate-nitrite nitrogen (NNN)) are present at very low concentrations across SOE monitoring sites in the mid Taieri. Based on LAWA, all three Taieri River sites and Sutton Stream at SH 87 rank in the best 25% of all river and stream sites monitored in rural areas across NZ.[5] This ranking likely also applies to the Nenthorn and Deep Stream sites but these sites were not displayed on LAWA (when accessed in March 2024).

A closer look at the *E. coli* results over the last five years indicates that the Taieri River at Sutton exceeded the action level (540 *E. coli*/100mL) of the national recreational water quality guidelines on over 12% of sampling occasions (Figure 4-2). Only the Taieri River at Allanton recorded more sample results over 540 *E. coli* per 100mL. This is revisited in Section 6.

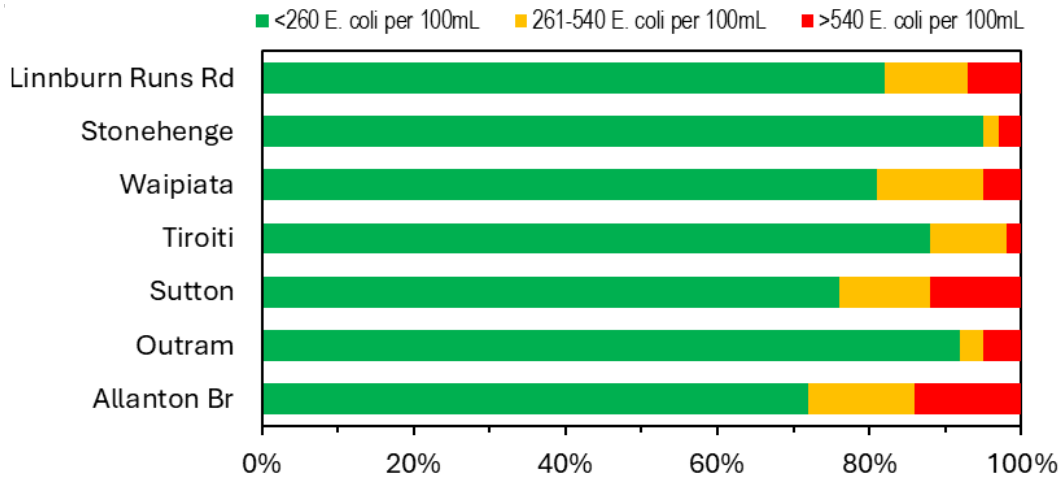

Figure 4-2: *E. coli* counts across all Taieri River SOE water quality monitoring sites, summarised in the form of percentage of sample results falling into the green/surveillance, amber/alert and red/action levels of the national MfE/MoH (2003) contact recreation guidelines. Based on monthly sampling between July 2017 and June 2022, reported in Appendix 1 of Ozanne et al. (2023).

Water temperature and dissolved oxygen

Unlike further upstream at Waipiata, water temperatures in the Taieri River at Sutton and Outram do not regularly exceed 20°C. High frequency measurements made by the ORC over the 20-year period ending February 2024 indicate that water temperatures only exceeded 20°C just over 4% of the time at Sutton and 3.4% of the time at Outram. The highest water temperature recorded to date was 27.7°C at Sutton on the afternoon of 30 January 2018 which followed a period of more than a month of peak daily water temperatures above 20°C.

In New Zealand, the Cox Rutherford Index (CRI) is commonly used to characterise summertime water temperatures and interpret the potential effects of water temperature on aquatic ecosystems. The CRI is the midpoint between the daily average and daily maximum temperatures and can be averaged over the five hottest days of a summer from a continuous water temperature record (Davies-Colley et al. 2013). Table 4-2 summarises the two component values of the CRI for the warmest summer (2017/18) calculated from ORC's Sutton and Outram data. The values are graded in accordance with bands A to D developed by Davies-Colley et al. (2013).

One consequence of elevated summertime water temperatures is a reduction in dissolved oxygen (DO) levels (warm water holds less oxygen), which can further stress invertebrate and fish life.

[5] Based on the median concentrations reported over the five-year period ending 30 June 2022.

Table 4-2: Cox Rutherford Index water temperature values for the Taieri River at Sutton and Outram for the warmest five days in summer 2017/18. Calculated from ORC data collected at 5-minute intervals.

Site	5-day period	Water temperature (°C)		Davies-Colley et al. (2013)*	
		Average daily	Average daily maximum	Band	Description
Sutton	27 Jan–31 Jan 2018	23.5	26.0	D	Significant thermal stress on a range of aquatic organisms
Outram	28 Jan–01 Feb 2018	23.2	24.5	C	Some thermal stress on occasion, with loss of certain sensitive insects and absence of certain sensitive fish

* Suggested bands only – water temperature is not an NPS-FM attribute.

While DO levels in many rivers are often close to 100% saturation, the Taieri River is typically characterised by lower DO levels, with a median of around 80% upstream at Waipiata[6]. This likely reflects a combination of the river's slow meandering flow, elevated water temperatures and inputs (e.g., decaying organic matter) from the associated wetlands in the Styx and Maniototo basins (Milne & Rados 2024). The median DO is higher at Sutton (around 86%).

The lowest DO measurements recorded at Sutton since continuous monitoring began in late October 2020 occurred on 5 March 2023 when DO levels dropped below 65% saturation for a short time. In mid-January 2021 DO levels dropped below 75% saturation for several days (minimum 6.4 mg/L on 17 January). A report prepared for Tiaki Maniototo on (much lower) DO levels at Waipiata during this same period identified that this was most likely due to a flood event in the upper catchment a few days prior; the low DO was due to either stagnant flood waters draining back into the river system or increased bacterial respiration from large inputs of organic matter into the river system (Wansbrough 2023).

High frequency monitoring of DO at Outram only began in early March 2023. To date, all DO measurements have been above 80% saturation. The median for the 12 months ending 1 March 2024 was 99.2%.

Ecological health

Ecological variables were not included in the ORC's most recent state and trend report. However, a separate biological monitoring report card for the 2017–2022 period[7] assigned an overall macroinvertebrate community health grade[8] of Band C to five of the six SOE sites, with Nenthorn Stream at Mount Stoker Road assigned to Band D (below the national bottom line). Most of these median grades were based on less than five years of data and so are indicative grades only, including the grades for the Taieri River mainstems sites at Sutton and Outram in the ORC's (2021) state and trend report. This earlier ORC report provisionally placed both Taieri River sites in Band C, based on the five-year median macroinvertebrate community index (MCI) metric. The NPS-FM narrative description for Band C is *"moderate to severe loss of ecological integrity"*. Based on the most recent (2022 and 2023) data supplied by the ORC, Sutton Stream at SH 87, Deep Stream at SH 87 and Taieri River at Outram returned higher invertebrate community health scores than the mainstem site at Sutton. Physical stream habitat features account at least in part for the lower invertebrate health metrics at Sutton; the site is characterised by run habitat and lacks the variety of flow (and potentially substrate) types that the other sites provide. The consistently lower scores for the Nenthorn Stream likely reflect low flows and instream habitat features rather than poor water quality.

[6] Based on high frequency measurements made by the ORC between October 2020 and October 2023.
[7] https://www.orc.govt.nz/media/14656/bio-monitoring-report-card.pdf
[8] Overall refers to the Average Score Per Metric (ASPM) in the NPS-FM. This index aggregates three other metrics that are averaged to indicate river/stream health: the MCI, the richness of Ephemeroptera, Plecoptera and Trichoptera (EPT taxa) and %EPT abundance.

In the ORC (2021) report, periphyton biomass was graded as Band C under the NPS-FM across all six SOE sites, translating to *"periodic short-duration"* nuisance (algal) blooms. These grades were derived from water column DRP concentrations rather than periphyton biomass measurements. However, recent periphyton biomass data for the Taieri River at both Sutton and Outram (collected between 2019 and 2022) also assigned these sites to Band C (Ozanne et al. 2023), suggesting that periphyton growth does reach nuisance amounts at times. This is likely to occur following extended dry periods without a "flushing flow" to remove the growth, as was observed in autumn 2024 (Figures 4-3 and Figure 4-4).

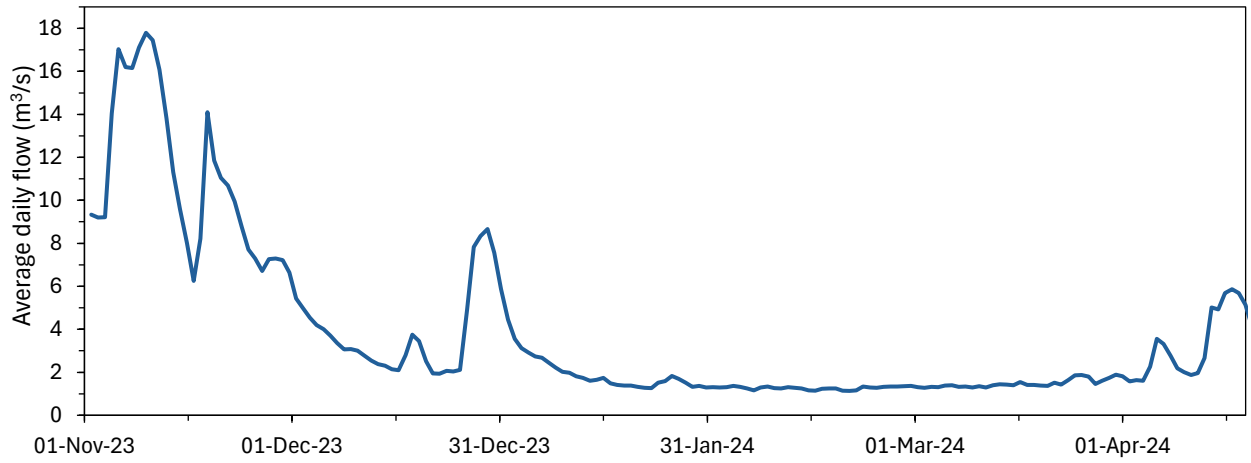

Figure 4-3: Average daily flows in the Taieri River at Sutton between November 2023 and April 2024. Nuisance riverbed coverage of periphyton further upstream (Figure 4-4) was observed after an extended period of low flows and warm weather. Source: ORC website, 3 May 2024.

Figure 4-4: Periphyton growth at nuisance levels on the bed of the Taieri River at Hyde-Macraes Road on 2 April 2024. Long filamentous algae (left) had attached to *Nostoc* cyanobacteria mats (right). Many species of *Nostoc* grow well in low nitrogen waters like the Taieri as they can fix nitrogen from the atmosphere. Photos: J. Milne.

4.1.2 Groundwater quality

The 2017–2022 groundwater quality state assessment included in Ozanne et al. (2023) was limited to three variables: nitrate-N, *E. coli* and arsenic. Monitoring data were compared against the Maximum Acceptable Values (MAV) of the NZ Drinking Water Standards (NZDWS).

For the shallow SOE well in the Strath Taieri:

- the median nitrate-N concentration was 1.45 mg/L, well below the NZDWS (and also below the 2.5 mg/L threshold above which groundwater quality is considered to be impacted by low intensity land use (Morgenstern & Daughney 2012),
- *E. coli* was detected on two occasions, breaching the NZDWS, and
- arsenic concentrations did not exceed the NZDWS on any occasion.

An earlier assessment of groundwater quality across Otago (Levy et al. 2021) incorporated data on additional nutrients and graded the results against the NPS-FM 2020 attribute bands. While these attribute bands only apply to surface waters and the concentrations do not necessarily reflect those in the groundwater at the point of entering surface water, this comparison recognises that groundwater – particularly shallow groundwater – interacts with the overlying surface water. The results for the shallow Strath Taieri well (Table 4-3) highlight that groundwater DRP concentrations are elevated compared to surface water concentrations.

Table 4-3: Summary of nutrient concentrations (mg/L) and NPS-FM 2020 attribute grades assigned to the ORC's sole SOE groundwater monitoring well in the mid Taieri catchment. Based on the results of water samples collected quarterly between late 2014 and December 2019, reported in Levy et al. (2021).

Site	Ammonia toxicity		Nitrate toxicity		DRP	
	Median	95th-ile	Median	95th-ile	Median	95th-ile
H43/0132 (Swansea Street)	0.005 A	0.049 A	1.5 B	1.7 B	0.039 D	0.054 C

4.1.3 Soil quality

The test results for (fluvial recent) soil samples collected from a sheep and beef drystock farm Middlemarch in March 2022 have recently been reported as part of a regional soil quality 'report card' (Button 2024). The report card provides a summary by land use across Otago rather than by catchment, so for this report we compared the Middlemarch sample results against soil quality indicator targets developed for regional councils (McKay et al. 2013). This exercise found that the only indicator of potential concern was Olsen-P which exceeded the upper end of its target range. Very high Olsen P concentrations are a concern as Olsen P is a measure of the amount of phosphorus in the soil that is available to plants; excessive levels can increase loss to waterways, contributing to nutrient enrichment and other impacts on water quality.

4.2 Insights from other recent monitoring and investigations

4.2.1 ORC water quality investigations

The ORC's 2010-11 upper Taieri water quality investigation included two sites on Lug Creek, one of the larger tributaries of the Taieri River draining the western side of the Rock and Pillar Range. The sites were located upstream and downstream of irrigated farmland at the Hyde Middlemarch Road and downstream of Ngapuna Road, a short distance from the creek's confluence with the Taieri. The investigation (Kitto 2012) identified significantly higher NNN and total nitrogen concentrations downstream (Table 4-4) and compared with other current SOE sites (refer Figure 4-1). However, ecological condition was very good at this (and the upstream) site, with good-excellent MCI scores of 120 and 125[9], a low coverage of fine sediment on the streambed, and the highest trout density of the ten Taieri River tributary sites fished (Kitto 2012). Trout condition at both sites was rated "fair", consistent with most of the upper catchment sites surveyed for fish. An extremely high *E. coli* count of 91,500 MPN/100mL – equivalent to that found in poorly treated wastewater – recorded at the downstream site on one sampling occasion during low base flows was attributed to the likely presence of a dead animal in the stream.

Information provided by the ORC indicates that macroinvertebrates were sampled in the Taieri River at Sutton on 10 different occasions throughout 2020 and on three different occasions in autumn 2021, with low flow monitoring one reason given (H. Manly, ORC, pers. comm. 2024). Based on the summary metrics provided by the ORC, the MCI scores were consistently 'fair' in 2020, ranging from 91 to 106. The autumn 2021 MCI scores were slightly lower, ranging from 89 to 94.

[9] It is unclear which score relates to which site due to a contradiction in the text and supporting graph in Kitto (2012).

Table 4-4: Summary of concentrations of total suspended solids (TSS), nutrients and *E. coli* in Lug Creek. Based on twice-monthly monitoring by the ORC between October 2010 and September 2011 (see Kitto 2012).

Variable	Lug Creek at Hyde Middlemarch Rd		Lug Creek near Taieri R confluence	
	Median	Range	Median	Range
TSS (mg/L)	<3	<3–17	4	<3–17
Ammoniacal-N (mg/L)	<0.01	all <0.01	<0.01	<0.01–0.07
NNN (mg/L)	0.010	0.009–0.020	0.214	0.007–0.836
Total N (mg/L)	0.09	0.05–0.21	0.38	0.20–0.97
Dissolved reactive P (mg/L)	0.014	0.009–0.020	0.013	0.007–0.034
Total P (mg/L)	0.018	0.011–0.052	0.023	0.011–0.047
E. coli (MPN/100mL)	17	1–680	98	1–91,500

4.2.2 DCC Middlemarch WWTP monitoring

The only information accessed for the Middlemarch WWTP was the ORC consenting reports prepared in response to the DCC's application for its current resource consent. Based on a summary of the monitoring presented in ORC's notification report (Black 2021), there is no evidence that the Middlemarch WWTP has any noticeable effect on water quality in the Taieri River downstream of the dry oxbow into which it discharges, despite receiving occasional loads of highly concentrated influent from an unknown source and high inflows relative to the size of the population it serves[10]. Wastewater is treated in a two-stage pond system and a constructed wetland before discharging to the oxbow. Although this treatment only achieves modest nutrient and pathogen removal compared with more advanced wastewater treatment systems, it is likely that contaminants remaining in the wastewater after treatment are mostly assimilated in the underlying groundwater before it reaches the river.

Taking the average dry weather discharge volume of 149 m^3/day and median nutrient concentration values for the wetland discharge presented in Black (2021), the Middlemarch WWTP discharges:

- 2.2 kg per day of total nitrogen, of which 45% is in the form of (plant-available) ammoniacal-N, and
- 0.5 kg per day of total phosphorus.

For context, these nutrient loads are estimated to be in the order of 10% and 30% of the median daily total nitrogen and total phosphorus loads, respectively, discharged from the Sutton Stream to the Taieri River further downstream.

4.2.3 Mid Taieri Wai ecological monitoring

Stream health was rated "fair" to good" for the six stream sites surveyed by the Mid Taieri Wai in 2023, based on overall scores for physical stream habitat quality (Figure 4-5). The sites on March Creek (near Middlemarch) and Sheepwash Creek (near Nenthorn) recorded the lowest scores but for different reasons. The March Creek site lacked good bankside vegetation cover and riparian buffers whereas the Sheepwash Creek site had significant amounts of deposited sediment, limited flow and poor habitat for aquatic animals. The macroinvertebrate sampling results confirmed this, with Sheepwash Creek returning a score of below 3, translating to an ecosystem health score of "degraded".[11] Sheepwash Creek also had very poor water clarity

[10] This is due to groundwater infiltration (estimated to make up around 75% of the dry weather inflow to the WWTP) and, in wet weather, stormwater inflow. In very wet weather, the WWTP *"operates much more akin to a combined stormwater and wastewater system"* with peak flows of over 350 m^3/day (Black 2021).

[11] This score is generated from a Macroinvertebrate Abundance Index (MAI), a simplified version of the commonly calculated MCI. See NIWA (2019) for the MAI scores and grades.

(0.32 m) on the day of the survey. While this was linked with high sediment inputs in the stream, the higher conductivity measurement from this site (350 µS/cm compared with 50-130 µS/cm across other sites) and a rusty discolouration suggest iron-rich groundwater inputs were also a contributing factor (Dale 2023).

The results of eDNA testing identified some significant freshwater biodiversity values. For example:

- Eldon's Galaxias was detected in Canton and Fortification streams and the (additional) Deep Stream tributary site,
- Taieri flathead galaxias was detected in Sheepwash Creek, and
- Longfin eel was detected in the Fortification Stream, and Deadbullock and March creek sites.

Brown trout were also detected in Fortification Stream, and Deadbullock and March creeks, with Dale (2023) suggesting that trout likely use the latter two sites for spawning over the winter.

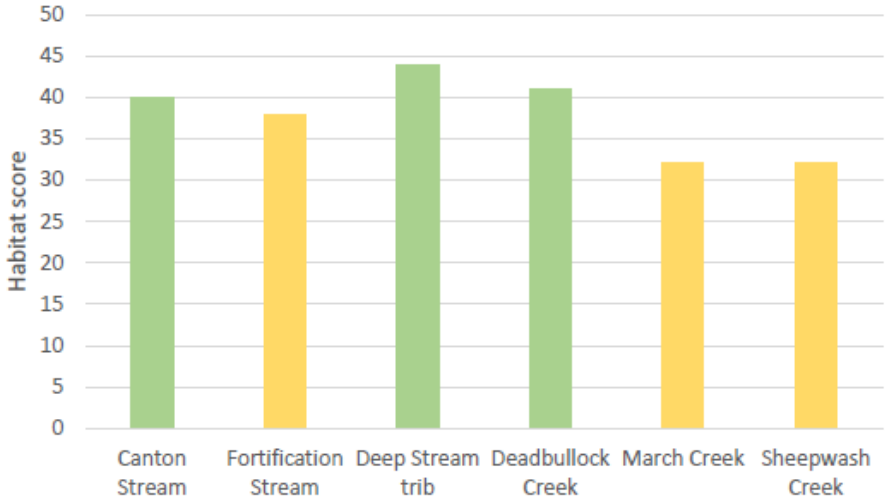

Figure 4-5: Overall scores for physical stream habitat quality, from an assessment in February 2023 using the NIWA SHMAK kit. The SHMAK habitat assessment uses a rapid survey that is similar to the widely used national rapid habitat assessment but only scores eight rather than ten components of stream habitat. Graph reproduced from Dale (2023).

4.3 Summary

Based on recent ORC state assessments (2017–2022 and, in some cases 2016–2021) and the results of other monitoring and investigations carried out over the last five or so years:

- The Taieri River and its tributaries are characterised by low concentrations of plant-available nutrients, in particular ammoniacal-N and nitrate-N, relative to median concentrations reported in other pastoral catchments in New Zealand.
- Median DRP concentrations are lower in the Taieri River mainstem at Sutton and Outram than upstream at Tiroiti and Waipiata. The sites at Sutton and Outram also record better (higher) dissolved oxygen levels and fewer occasions of elevated water temperatures than the equivalent high frequency monitoring site at Waipiata.
- Shallow groundwater north of Middlemarch has higher concentrations of plant-available nutrients compared with surface water sites but the median concentrations are not considered high relative to national benchmarks for groundwater quality.
- All three Taieri River mainstem sites are graded 'poor' for suspended fine sediment, based on a conversion of turbidity measurements to visual clarity and comparison against NPS-FM attribute bands. However, this conversion is problematic for tannin-stained waters.
- *E. coli* indicator bacteria counts are higher at Sutton than Tiroiti and Outram, and failed to meet the safe/surveillance level of the national recreational water quality guidelines on more than 25% of sampling

occasions over the last five years. This site, together with Sutton Stream at SH 87, falls into Band D of the NPS-FM for *E. coli*.

- The Taieri River monitoring sites at Sutton and Outram both appear to experience nuisance amounts of periphyton growth at times and macroinvertebrate health falls into Band C of the NPS-FM, consistent with all mainstem sites in the upper Taieri catchment. Recent data for the three tributary sites indicates that invertebrate communities are in better condition in Sutton Stream and Deep Stream but poor in the Nenthorn Stream at Mount Stoker.
- Treated wastewater from Middlemarch does not appear to have any measurable impact on water quality in the Taieri River.
- Results of one-off ecological surveys carried out by the Mid Taieri Wai across six stream sites during autumn 2022 identified a lack of riparian vegetation and sedimentation of the stream bed as having the biggest impact on stream health. Despite this, eDNA testing confirmed part of the mid Taieri catchment supports some significant native freshwater fish values.

5 Trends – is water quality getting better or worse?

The most recent assessment of trends in water quality over time in the mid Taieri catchment was carried out as part of a regionwide assessment of river, lake and ground water quality in Otago. This assessment was carried out by LWP Ltd (Fraser et al. 2023a, 2023b) and reported in Ozanne et al. (2023). This section summarises the key findings of trends in water quality reported for the following SOE sites:

- the Taieri River at Tiroiti, Sutton and Outram, the Nenthorn Stream at Mt Stoker and Deep Stream at SH 87 over a 10-year period ending on 30 June 2022,[12] and
- groundwater well H43/0132 over a 5-year period ending on 30 June 2022.

The LAWA website also reports trends in river health (for the last 5 and 10 years), with the assessments updated annually around September.

Understanding trend assessments

Assessment of trends over time complements information on current state by providing information on whether the state of water quality is getting *better or worse*. State and trend results therefore need to be considered together to understand river health.

Trend assessment methods applied to water quality and ecological data in New Zealand are statistically based and have evolved over time, resulting in differences in interpretation and reporting. The current recommended approach (Snelder et al. 2021) has been used in national and most regional SOE reporting for at least five years. This approach is based on the view that a trend always exists, but often there is not enough precision in the dataset to confidently say if the trend is increasing or decreasing. Previously trend results falling into this category were classified as "no trend" and where trends were detected, they were only reported if they had a very high of level of statistical significance.

Trend assessments are now reported based on bands of statistical confidence and associated descriptions, ranging from a low confidence of 33-66% ("as likely increasing as decreasing") to >99% confidence ("virtually certain"). The same bands and descriptions are not always universally applied.

Trend direction is sometimes reported on its own (e.g., LAWA, Ozanne et al. 2023) but this only provides a part of the picture. The *trend magnitude* or size is also important as this indicates the *rate of change* (increase or decrease) in water quality over the time period assessed. There may be a virtually certain increase in nitrate-N concentrations at a site over a 10-year period, indicating a deterioration in water quality, but the environmental significance of that increase depends on:

- what the current state of water quality is (e.g., is it above, below or approaching a critical guideline or standard?), and
- how quickly it is increasing (i.e., the rate of change).

Trend assessments also require the data analyst to make decisions about what data to include or exclude to ensure a robust assessment. Some of these 'data filtering' decisions are subjective, meaning two sets of assessments may not produce exactly the same results. This is often the case when multiple sites and long timeframes are being assessed (e.g., regional or national reporting) because of changes in the measurement frequency or methods that, if not accounted for, would prevent a robust comparison between sites. This applies to the ORC's SOE data and effectively means that sometimes not all of the data available for an individual site are used in regionwide trend assessments.

[12] Although the report also assessed river water quality trends over 20 years, none of the ORC's mid Taieri SOE sites had a record of sufficient length to be included. The Sutton Stream record was also too short to be assessed for trends over the 10-year period.

5.1 Surface water quality

Many more improving than degrading trends in water quality were observed for the 10-year period ending 30 June 2022. Overall, the only directions of trend (i.e., improving or deteriorating) classified as 'extremely likely' or 'virtually certain' and with a trend rate that could be quantified (Table 5-1) were:

- decreasing turbidity (i.e., improving visual clarity) in the Nenthorn Stream at Mt Stoker Road and Deep Stream at SH 87,
- decreasing phosphorus concentrations in the Taieri River at Tiroiti and Outram, and in the Nenthorn Stream at Mt Stoker Road (i.e., improving trends),
- increasing total N concentrations in the Taieri River at Tiroiti (i.e., a deteriorating trend), and
- increasing *E. coli* concentrations in Deep Stream at SH 87 (i.e., a deteriorating trend).

An earlier trend assessment (ORC 2021) for the 10-year period ending on 31 August 2020 indicated a much higher (and probably incorrectly calculated or reported) rate of total N increase for the Taieri River at Tiroiti (0.0135 mg/L per year).

Table 5-1: Summary of key trends in water quality at five sites within the mid Taieri catchment for the 10-year period ending 30 June 2022. Simplified from the results reported by Ozanne et al. (2023) – green and red cells indicate improving and deteriorating trends, respectively; yellow cells indicate the trend direction was unclear. Black arrows indicate both high confidence in the trend direction and a trend rate that was able to be quantified (presented as percentage change per year, extracted from LWP data files provided by the ORC). Amm. N is ammoniacal-N; NNN is nitrate-nitrite N.

Site	Amm. N	NNN	Total N	DRP	Total P	Turbidity	*E. coli*
Taieri R at Tiroiti			↑ 2.1%	↓ 4.3%	↓ 3.5%		
Taieri R at Sutton							
Nenthorn S at Mt Stoker		*Not analysed*		↓ 7.2%		↓ 6.5%	
Deep S at SH 87		*Not analysed*				↓ 3.1%	↑ 4.7%
Taieri R at Outram				↓ 6.1%	↓ 4.8%		

The most recent information found on trends in macroinvertebrate health in the mid Taieri catchment are for two NIWA sites that are no longer monitored; Taieri River at Tiroiti and Sutton Stream at SH 87. Data for these sites[13] were included in the *Our freshwater 2023* national SOE report which, for the 10 year-period ending summer/autumn 2020 found:

- a "very likely" deteriorating trend in MCI score of 2.2% per year at Tiroiti, and
- a "likely" improving MCI score at Sutton (1% per year).

5.2 Groundwater quality

The groundwater quality trend assessment results reported by Ozanne et al. (2023) were limited to nitrate nitrogen and arsenic but additional variables and information on rates of change were included in the trend assessment output files provided by the ORC. For the five-year period ending 30 June 2022, 'virtually certain' increases in nitrate-N and total N concentrations of over 9% per year were identified for well H42/0132 near Middlemarch.

[13] Accessed from the MfE website (May 2024): https://data.mfe.govt.nz/table/109669-river-water-quality-macroinvertebrate-community-index-trends-1991-2020/. NIWA data for the Taieri River at Outram were not assessed for 10-year trends.

5.3 What might be behind the trends?

Ozanne et al. (2023) and earlier regionwide SOE state and trend reports (e.g., Uytendaal et al. 2018), point to a lack of information on catchment- and local-scale land use and land management practices to provide evidence-based commentary on drivers and direction of water quality trends. This makes it is difficult to state with confidence the reasons behind the trends summarised in this section. As outlined in Milne and Rados (2024), decreasing (i.e., improving trends) in turbidity and concentrations of phosphorus observed for the Taieri River at Tiroiti may may be due to changes in irrigation and other farming practices in the Maniototo (e.g., a shift from flood-based to spray irrigation methods and improved stock exclusion).

5.4 Summary

- The most recent trend assessments indicate several aspects of water quality in the mid Taieri catchment improved over the 10-year period ending June 2022. Over the ten years, turbidity and concentrations of phosphorus decreased across all sites. However, there was also evidence of increasing plant-available nitrate-N concentrations in the Taieri River at Tiroiti, and in the shallow groundwater at a site monitored near Middlemarch. The reasons for the observed trends are unclear.
- No up-to-date information is available on trends in ecological variables such as macroinvertebrates as until recently, fewer sites were monitored for these variables. Macroinvertebrate data for former NIWA monitoring sites on the Taieri River at Tiroiti and Sutton Creek at SH 87 assessed over the 10 year-period ending in 2020 returned deteriorating and improving trends in macroinvertebrate community health, respectively, but statistical confidence in the direction of these trends was not high.

6 Issues, gaps and priorities

The monitoring and investigation results summarised in sections 4 and 5 indicate that water quality in the mid Taieri catchment is 'very good' and has improved in some aspects over the last 10 years. However, when compared against the NPS-FM 2020 attribute bands, several sites are classified as "poor" for sediment and the Taieri River at Sutton and Sutton Stream at SH 87 are affected by periodic faecal contamination. There are also some gaps in knowledge and understanding about the ecological condition of the river and its tributaries.

6.1 Sediment

Fine sediment (<2 mm in diameter) is a known 'master' stressor on river and stream health. In naturally cobble and gravel bedded rivers and streams like the Taieri River and its tributaries, fine sediment:

- reduces water clarity when suspended in the water column, reducing aesthetic values, light penetration for plant growth and the ability of fish to see their prey,
- can smother the bed, reducing the diversity and quality of the cobble substrate habitat for aquatic life with flow-on impacts (e.g., reduced diversity of aquatic life, loss of trout spawning habitat), and
- carries contaminants that readily attach to it, most commonly phosphorus, pathogens and metals, with flow-on effects for ecosystem health and reduced water quality for recreational and other uses.

The NPS-FM includes two sediment attributes, one for the water column (suspended fine sediment) and one for the riverbed (deposited fine sediment). There is more than one method to measure suspended and deposited fine sediment but the NPS-FM defines:

- suspended fine sediment as visual clarity, not the closely related measures of turbidity or concentration of suspended sediment, and
- deposited fine sediment as the percentage bed cover of fine sediment, determined as an average of visual estimates of cover made at 20 locations across the river.

In terms of suspended fine sediment, the ORC currently only routinely measures turbidity at SOE sites and uses a national equation established by Franklin et al. (2020) to convert turbidity measurements to an estimate of visual clarity so that an NPS-FM band can be determined. Although the NPS-FM allows for this, neither the national equation nor the NPS-FM attribute thresholds are applicable to naturally highly coloured brown-water streams (Franklin et al. 2019). This is because, while turbidity and visual clarity are usually closely correlated, visual clarity measurements (unlike turbidity) reflect both the concentration of suspended fine sediments and water colour (e.g., because of tannin staining). The current assignment of D bands (i.e., below the national bottom line or minimum acceptable state) for the Taieri River at Tiroiti, Sutton and Outram will at least partially be due to natural tannin-staining contributing to "lower" visual clarity. It is also worth noting that a river that is affected by natural processes such as tannin-staining is exempt from meeting the national bottom line for visual clarity.

Irrespective of the NPS-FM grading, median turbidity is already high at Tiroiti relative to further upstream and is higher again at Sutton (refer Figure 4-1). It is not known if lower visual clarity at Sutton is due to sediment inputs from tributaries (none are monitored between these two locations), a response to localised sediment inputs (e.g., from bank erosion at or upstream of the Sutton site) or potentially gravel extraction activities which were, at least historically, carried out regularly in the Strath reach of the Taieri (Ryder & Tocher 2020).

The ORC does not routinely monitor deposited fine sediment cover at any SOE sites in the mid Taieri catchment. Raw data provided by ORC staff for assessments of physical habitat carried out in March 2021 and June 2022 indicated that riverbed cover of fine sediment was low at Sutton but higher (~20-30%) at Outram. Assessments carried out by Mid Taieri Wai in February 2022 found significant deposits of sediment at sites on Sheepwash Creek and a tributary of Deep Stream. Dale (2023) identified low level stock access and, in the Deep Stream tributary, fresh erosion and bank collapse following significant flooding in the months prior to the survey, as the primary sources of the sediment.

Evidence of stock access to streams and exposed bank soil was observed during a drive through parts of the Strath Taieri in early April. This also applied to the Taieri main stem in places (Figure 6-1) and although clean river gravels dominated the riverbed (except where thick periphyton growth was present – refer Figure 4-4, Section 4.1.1), sediment build up was evident in some of the deeper pools.

Figure 6-1: Pockets of fine sediment on the channel margins of the Taieri River at Sutton (left) and Tiroiti (right) on 2 April 2024. Overall, the riverbed gravels at these sites were largely clean. More than a dozen trout were observed on the downstream side of the Sutton-Mount Ross Road bridge.

6.2 Nutrients

6.2.1 Nitrogen

The forms of nitrogen most readily taken up by periphyton and aquatic plants (macrophytes) are the dissolved inorganic forms (ammoniacal-N, nitrite-N and nitrate-N), which are present at very low concentrations in the mid reaches of the Taieri River, especially when compared with other monitored rivers in rural areas of New Zealand[14]. Similar to all other monitored Taieri River sites, total nitrogen concentrations are much higher (Figure 6-2), indicating that most nitrogen is present in organic forms (e.g., amino acids, plant tissue and decayed leaf matter). Nutrient forms are not fixed; under the right conditions, one form can convert to another and become available, 'locked up' or lost from the system (e.g., by denitrification).

Median concentrations of plant-available nitrogen are also low in the Sutton, Nenthorn and Deep streams. Much higher concentrations were reported in the lower reaches of Lug Creek (Kitto 2012) but this was based on an investigation carried out over a decade ago. The ORC's only long-term groundwater monitoring well in the mid Taieri catchment had a median nitrate-N concentration of 1.45 mg/L over the five-year period ending June 2022. This is reasonably low when compared with shallow unconfined groundwater in other rural areas, although concentrations did increase at an average rate of over 9% per year over the five years.

The Taieri River appears to be nitrogen-limited (McDowell & Kitto 2013, Kitto 2012) so an increase in nitrogen would likely stimulate plant growth more than additional phosphorus would. Information on periphyton growth is limited but there is some evidence that it reaches nuisance levels in some reaches at times of extended low flow (refer Section 4.1.1). This means a close watch should be kept on trends in concentrations of plant-available nitrogen in ground and surface water if proposals to increase irrigation reliability and the area of irrigated land in the Strath Taieri go ahead (Chrystal & O'Neill 2018). Nitrate is generally readily leached from soils to groundwater, and losses can be very high under intensive land uses (e.g., vegetable growing, dairying).

[14] Based on a comparison of median concentrations reported on LAWA (March 2024).

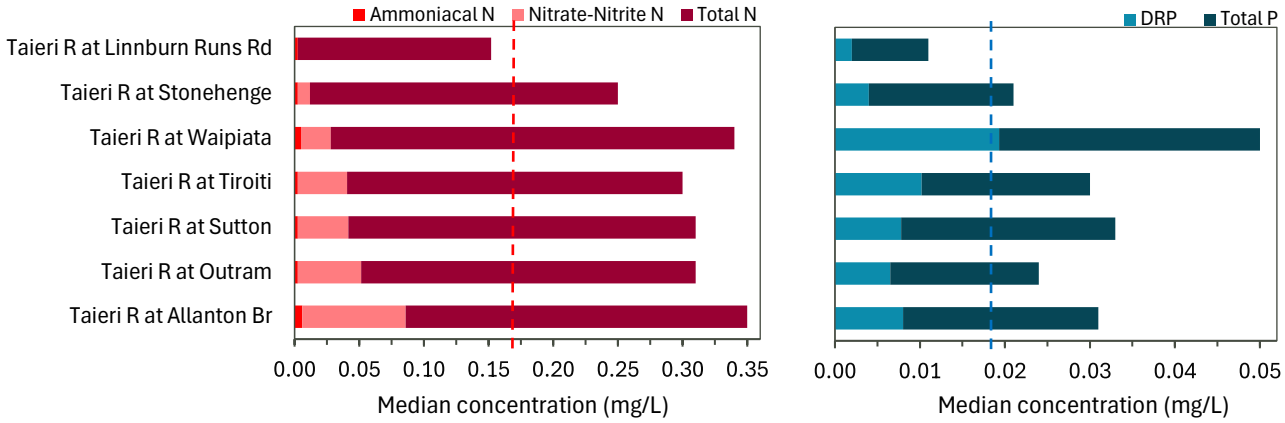

Figure 6-2: Median concentrations of nitrogen (left) and phosphorus (right) recorded by the ORC in mainstem Taieri River sites. ORC data drawn from LAWA in May 2024. The full length of each bar represents the total N or P concentration, with the lighter coloured portions representing the plant-available fractions. The vertical red dashed line represents the once commonly applied ANZECC (2000) NNN 'benchmark' for upland rivers (presented for context only, to illustrate that NNN concentrations are low). The vertical blue dashed line represents the boundary of Bands C/D under the NPS-FM 2020 (note there is no national bottom line for DRP).

6.2.2 Phosphorus

Median concentrations of plant-available phosphorus (DRP) are low in the Sutton, Nenthorn and Deep streams compared with other monitored rivers in rural areas and fall within Band A of the NPS-FM. The median DRP concentration in the Taieri River at both Sutton and Outram is also lower than that recorded on the mainstem higher in the catchment at Waipiata and Tiroiti (Figure 6-2).

6.3 *E. coli*

The most recently reported five-year median *E. coli* counts are low for Nenthorn and Deep streams at SH 87 but place the Taieri River at Sutton and Sutton Stream at SH 87 in Band D of the NPS-FM (Ozanne et al. 2023). The Taieri River site median only just falls into this band and would otherwise be assigned Band C based on the other three *E. coli* metrics that determine the band classification. In contrast, Sutton Stream also falls into Band D because of the high (>34%) proportion of test results above 260 *E. coli*/100mL (the amber/alert level of the national microbiological water quality guidelines), a level above which there is deemed an increased risk of infection from exposure to pathogens. It is worth noting that the five-year 95th percentile values at both sites align with Band B and C, respectively (Ozanne et al. 2023). This means that there are not large numbers of particularly high *E. coli* concentrations in either dataset (i.e., faecal contamination is generally at a "low or moderate" level and chronic rather than acute in nature).

No tributary sites are monitored upstream of the Taieri River at Sutton and no faecal source tracking (FST) has been performed to date. However, some insights into the likely source(s) of the periodic faecal contamination at this site and Sutton Stream at SH 87 can be drawn from looking at rainfall prior to sampling and river flows, as well information collected at other stream sites by the Mid Taieri Wai.

Figure 6-3 provides a comparison of all water sample test results recorded to date that exceed the red/action level of the national microbiological water quality guidelines against rainfall in the three days prior to sampling. For the Taieri River at Sutton, five of the eight highest *E. coli* results coincided with at least 20 mm of rainfall prior to sampling. On three of these occasions, the wet weather coincided with river flows above 25 m^3/s, indicating that runoff from the upper Taieri catchment was likely responsible (although there are no corresponding *E. coli* data for the Tiroiti site on these dates to confirm this). However, given that four of the 18 action level results coincided with only around 5 mm of rainfall prior to sampling and low or stable river flows on the day of sampling, this suggests that dry weather sources of faecal contamination also exist at times. This is likely also the case for Sutton Stream; the highest result at this site (3,840 *E. coli*/100mL) was recorded in April 2019 in the absence of any rainfall (Figure 6-3) when the stream flow was just 0.72 m^3/s.

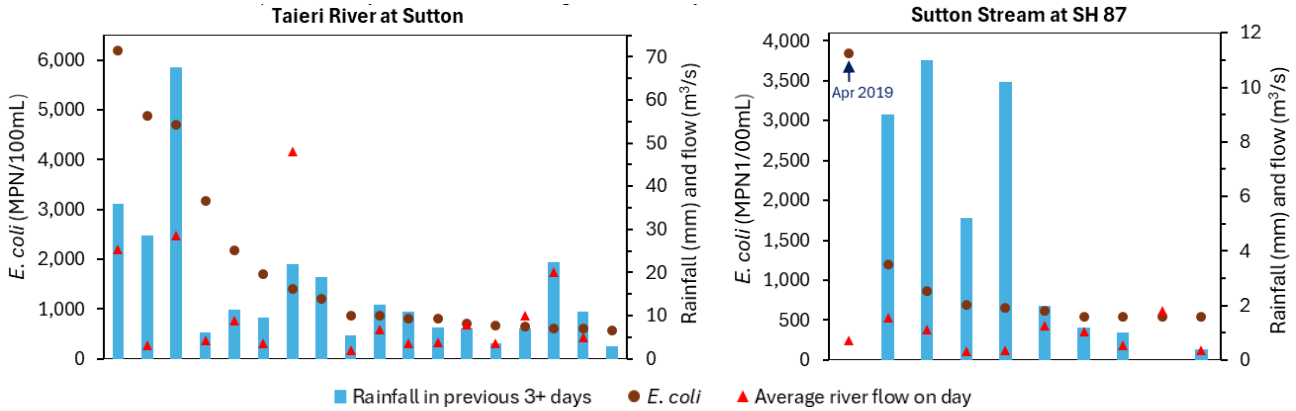

Figure 6-3: *E. coli* counts above the red/action level (540 *E. coli*/100mL) of the national microbiological water quality guidelines compared with rainfall and river flow. Based on all ORC monthly *E. coli* testing results (2006–2024 for the Taieri River and 2017–2024 for Sutton Stream), rainfall recorded at Mt Stoker and Middlemarch, and average flow on the day of sampling at each site, extracted from the ORC's Environmental Data Portal. Note: The scales on the two graphs are different.

At both sites, most of the action level results occurred in the warmer months (late spring to early autumn), including on four occasions each over the summer in the absence of significant rainfall (i.e., at or near base flows). The tendency for *E. coli* counts to be higher in summer is consistent with findings elsewhere in the Taieri catchment (Muirhead & Meenken 2018) and New Zealand (e.g., Whitehead et al. 2019). FST sampling carried out across rural river catchments in Southland in 2015 and 2016 showed that wildfowl and ruminant animals, including cows and sheep, are key sources of faecal contamination in base flow (i.e., dry) conditions (Moriarty et al. 2019a-d). In contrast, for samples collected following rainfall, ruminants typically dominated the faecal input (although waterfowl sources were still present).

The Mid Taieri Wai's autumn 2022 eDNA sampling and stream habitat assessment results support the view that stock contribute to elevated *E. coli* counts in surface waters in the mid Taieri. Cattle and sheep DNA were present in the highest concentrations of all mammalian sources of eDNA detected across the six stream sites sampled, with the concentration of cattle eDNA ten times higher than that of sheep at several sites (Dale 2023).[15] The eDNA test results also suggest that Mallard and Muscovy duck contribute to faecal contamination in March Creek.

Evidence of stock access was observed during a drive through parts of the Strath Taieri basin in early April (Figure 6-4). Extended reaches of many streams, including the Nenthorn Stream and Sheepwash Creek, were dry but faecal matter deposited within or near the channel could be mobilised downstream under rainfall. Evidence of direct stock access to the Taieri River mainstem was also observed at several locations.

[15] Note the concentration of eDNA present includes all sources of DNA, both faecal and non-faecal sources, and both living and non-living sources. Current eDNA testing is also only reliable for detecting the *presence* of a species and replicate testing is needed for robust results; the concentrations reported are a signal strength and do not necessarily reflect the number of individual species present.

Figure 6-4: Evidence of stock access to the Taieri River (left) and a dry streambed (right) on 2 April 2024.

Limitations with the current *E. coli* guidelines

E. coli is a long-established and accepted, but imperfect, indicator of the risk to human health from pathogens that are much more expensive to test for.

One limitation with the MfE/MoH (2003) guidelines on which the NPS-FM *E. coli* attributes bands are based, is that they do not account for different levels of pathogenicity that may be associated with different sources of faecal matter. For example, in combining the results of faecal source tracking with a quantitative microbial risk assessment (QMRA)* in a rural catchment in Texas, Gitter et al. (2020) found that the highest health risk was associated with Norovirus, the pathogen representing human waste. This was despite faecal indicator bacteria from non-human sources being the most frequently present in repeated water testing. After humans, dairy cow faecal matter presented the next greatest risk, ahead of the wildlife sources (including birds). This suggests that the proportion of a single source contributing to the overall *E. coli* count does not indicate the overall human health risk.

The risks of gastrointestinal illness from exposure to recreational waters were also found to vary by source in the US; the risk differed little between waters impacted by human sources and fresh cattle faeces, but the impacts of gull, chicken and pig faeces appeared to be much lower (Soller et al. 2011).

* A QMRA is currently the most robust method available to assess the risks to human health from exposure to faecally contaminated water. It is regularly carried out in New Zealand when assessing the effects of wastewater treatment plant discharges to rivers, lakes or coastal waters.

6.4 Gaps and priorities

Long-term ecological and physical stream habitat data are lacking for the mid Taieri catchment. While water column nutrient concentrations are low across all five surface water monitoring sites, there is some evidence to indicate periphyton biomass can reach nuisance levels in the main stem of the Taieri River during dry periods. Macroinvertebrate health in the Taieri River at Sutton is also assigned to Band C under the NPS-FM ("moderate to severe loss of ecological integrity"), consistent with all mainstem sites in the upper Taieri catchment. Two recent annual surveys of the tributary sites monitored by the ORC indicate that invertebrate communities are in better condition in Sutton Stream and Deep Stream but are 'poor' – likely below the the national bottom line (Band D) – in the Nenthorn Stream at Mount Stoker. Understanding the reasons for this is difficult because information on streambed periphyton cover and physical habitat quality, including fine sediment cover, is largely lacking.

The ORC does not currently monitor any sites on tributaries between Tiroiti and Sutton and an investigation of water quality and ecology across a few of these may be worthwhile, particularly given the apparent deterioration in visual clarity and increase in *E. coli* counts between these mainstem sites. One-off ecological monitoring by the Mid Taieri Wai indicates that low level stock access is likely contributing to increased

sedimentation and faecal contamination in some areas. This includes sites within the Lee Stream catchment, one of the largest subcatchments in the southern part of the mid Taieri catchment. The ORC has not monitored water quality or ecological health in this subcatchment since 2014.

Collection of information on subcatchment scale land use and land management practices would be useful to help understand drivers and direction of water quality trends in the mid Taieri. This will be particularly important should proposals to increase the area of irrigated land go ahead; collation of existing and collection of new information may already be underway at the farm or subcatchment scale to support the development of freshwater farm plans (e.g., mapping of critical source areas).[16] On the list of information to record should be details of management actions taken to maintain or improve water quality and catchment health. A national register is now available to capture this information in a standardised way: https://healthywaterways.nz.

6.4.1 Monitoring-related considerations

The ORC should consider:

- carrying out more comprehensive assessments of periphyton and fine deposited sediment cover at all SOE sites in the mid Taieri (ideally monthly for a period of three years),
- ensuring rapid assessments of physical stream habitat quality are carried out annually at all SOE sites when macroinvertebrate samples are collected,
- investigating the source of faecal contamination and potential sediment-related issues in the Sutton area, and
- establishing a site-specific relationship between turbidity and visual clarity for naturally tannin-influenced SOE sites to inform assessments of the suspended fine sediment attribute under the NPS-FM.

As noted in Milne (2024), establishing a site-specific relationship between turbidity and visual clarity at the Taieri River sites in the upper catchment at Linnburn Runs Road or Stonehenge will enable a more meaningful catchment-specific attribute target state to be set for the Taieri mainstem. Some historic paired turbidity and visual clarity data do exist, with NIWA's 1989–2016 record for Tiroiti the most comprehensive available. However, sediment properties can change over time and additional data collection is recommended.

Lastly, monitoring smaller streams is likely to detect impacts or improvements associated with land use actions quicker than monitoring the main stem of higher order rivers such as the Taieri (McDowell et al. 2024). This should be kept in mind by the Mid Taieri Wai and others interested in carrying out monitoring.

[16] A recent example of good farm-scale data collation is the maps of land parcels under different types of irrigation methods (e.g., border dyke, centre pivot) included in a water takes consent application for the Pig Burn catchment (see Dicey 2020).

Acknowledgements

This report was funded by the Ministry for the Environment's A2E Fund and the Upper Taieri Wai through the Healthy Taieri Integrated Farm Planning project. Thanks to Sally Dicey (Whirika Consulting) for initiating this work and providing valuable background information.

Many people and organisations contributed information to this report. Thanks to:

- Wayne Worth, Rachel Ozanne, Helen Trotter, Erik Button and Ruth Topless (Otago Regional Council) for supply of monitoring and investigation data
- Leah Day and Sophie Butt (ORC) for supply of resource consent information
- Chris Kavazos, Oliver Wigmore and Sue Clearwater (Department of Conservation) for supply of catchment reports and monitoring programme details
- Matt Dale (Waterscape Connections) and Susie McKeague (McKeague Consulting) for access to Mid Taieri Wai monitoring and Strath Taieri nitrogen modelling reports, respectively
- Scott Campbell (Dunedin City Council) for supply of source water monitoring locations and data associated with Dunedin City's potable water supplies in the Taieri catchment
- Chris Garden (Whirika Consulting) for supply of GIS layers
- Kate Wilson, Steven Nichol and Chris Arbuckle for local catchment insights.

References

Australian and New Zealand Environment and Conservation Council (ANZECC). (2000) Australian and New Zealand guidelines for fresh and marine water quality, volume 1, the guidelines. Agriculture and Resource Management Councils of Australia and New Zealand, Canberra.

Black K. (2021) ORC Notification Recommendation Report: RM21.037, Middlemarch Wastewater Treatment System. Otago Regional Council, 15 September 2021. 26 p.

Button E. (2024) Land and soil monitoring update. Report No. SPS2404 prepared for the Otago Regional Council's Environmental Science and Policy Committee, 27 June 2024.

Crystal J, O'Neill K. (2018) Modelled N losses to water from dryland and irrigated land in the Strath Taieri catchment. AgResearch Client Report No. RE450/2018/010 prepared for McKeague Consultancy Ltd. 39 p.

Dale M. (2023) Ecological monitoring of six streams in the mid-Taieri catchment. Report prepared for Mid Taieri Wai by Waterscape Connections. 33 p.

Davies-Colley R, Franklin P, Wilcock B, Clearwater SJ, Hickey CW. (2013) National Objectives Framework – temperature, dissolved oxygen and pH. NIWA Client Report No. HAM2013-056 prepared for Ministry for the Environment.

Dicey S. (2020) Pig Burn – collective replacement of permits to take and use surface water: Resource consent application and supporting information. McKeague Consultancy Ltd client report. 103 p + appendices.

Franklin P, Stoffels R, Clapcott J, Booker D, Wagenhoff A, Hickey C. (2019) Deriving potential fine sediment attribute thresholds for the National Objectives Framework. NIWA Client Report No. 2019039HN prepared for the Ministry for the Environment. 290 p.

Franklin P, Stoffels R, Booker D. (2020) Contract 23184: Task 2 — Turbidity and visual clarity threshold conversion. Client memorandum prepared for the Ministry for the Environment, 13 March 2020. 10 p.

Gerard P, Closs GP, Matthaei CD, Mora-Teddy A, Schallenberg M. (2024) Impacts of climate change on the Tāiari River and tributaries. Report prepared for the Department of Conservation.

Gitter A, Mena KD, Wagner KL, Boellstor DE, Borel KE, Gregory LF, Gentry TJ, Karthikeyan R. (2020) Human health risks associated with recreational waters: Preliminary approach of integrating quantitative microbial risk assessment with microbial source tracking. *Water* 2020(12): 327.

Goldsmith MJ. (2023) Climate change impacts and risks for the Taiari catchment. Report prepared for the Department of Conservation by GHC Consulting Ltd.

Kitto J. (2012) Water quality effects on instream values in the Upper Taieri. Otago Regional Council. 57 p.

Levy A, Ettema M, Xiaofeng Lu X. (2021) State of the Environment groundwater quality in Otago. Otago Regional Council science report. 192 p.

Macara GR. (2015) The climate and weather of Otago. 2nd edition. NIWA Science and Technology Series No. 6. 42 p.

Mackay A, Dominati E, Taylor MD. (2013) Soil quality indicators: The next generation. AgResearch Client Report RE500/2012/025 prepared for Land Monitoring Forum of regional councils. 155 p.

Malthus TI, Mitchell SF. (1988) Agricultural development and eutrophication of Lake Mahinerangi, New Zealand. *SIL Proceedings, 1922-2010*, *23*(2), 1,028–1,031.

McDowell RW, Noble A, Kittridge M, Ausseil O, Doscher C, Hamilton DP. (2024) Monitoring to detect changes in water quality to meet policy objectives. *Scientific Reports* 14(1):1914. https://doi.org/10.1038/s41598-024-52512-7.

Milne J. (2024) Water quality in the lower Taiari/Taieri catchment: A summary of monitoring activities and findings. Report prepared for the Upper Taieri Wai by Traverse Environmental Ltd. 53 p.

Milne J, Rados D. (2024) Water quality in the upper Taiari/Taieri catchment: A summary of monitoring activities and findings. Report prepared for the Upper Taieri Wai by Traverse Environmental Ltd. 56 p.

Ministry for the Environment. (2020) Action for healthy waterways: Guidance on look-up tables for setting nutrient targets for periphyton. Ministry for the Environment, Wellington.

Ministry for the Environment. (2022) Guidance on look-up tables for setting nutrient targets for periphyton. 2nd edition. Ministry for the Environment, Wellington.

Ministry for the Environment/Ministry for the Environment. (2003) National microbiological water quality guidelines for marine and fresh water recreational areas. Ministry for the Environment, Wellington.

Morgenstern U and Daughney C. (2012) Groundwater age for identification of baseline groundwater quality and impacts of land-use intensification — the National Groundwater Monitoring Programme of New Zealand. *Journal of Hydrology*, 456/457: 79–93.

Moriarty EM, Pantos O, Coxon S. (2019a) Sources of pollution in the Aparima Freshwater Management Unit. ESR Client Report No. CSC 19008 prepared for Environment Southland. 133 p.

Moriarty EM, Pantos O, Coxon S. (2019b) Sources of pollution in the Mataura Freshwater Management Unit. ESR Client Report No. CSC 19007 prepared for Environment Southland. 134 p.

Moriarty EM, Pantos O, Coxon S. (2019c) Sources of pollution in the Oreti Freshwater Management Unit. ESR Client Report No. CSC 19005 prepared for Environment Southland. 126 p.

Moriarty EM, Pantos O, Coxon S. (2019d) Sources of pollution in the Waiau Freshwater Management Unit. ESR Client Report No. CSC 19006 prepared for Environment Southland. 77 p.

NIWA. (2019) SHMAK Stream Health Monitoring and Assessment Kit User Manual, ISSN 1774-2631, ISBN 978-0-473-49972-3.

ORC (2006a) River and stream health: Taieri River annual monitoring summary 2005. Report card. 4 p.

ORC (2006b) Review of state of the environment surface water quality monitoring sites. Unpublished Otago Regional Council report, March 2006. 28 p.

ORC (2021) Taieri FMU river & lake water quality: State and trends. Otago Regional Council science report. 39 p.

ORC (2023) Biomonitoring report card: 2017 to 2022. Otago Regional Council. 16 p. https://www.orc.govt.nz/media/14656/bio-monitoring-report-card.pdf

O'Sullivan K, Goldsmith M, Palmer G. (2013) Natural hazards on the Taieri Plains, Otago. Otago Regional Council report. 102 p.

Ozanne R, Levy A, Borges H. (2023) State and trends of rivers, lakes, and groundwater in Otago: 2017–2022. Otago Regional Council science report, May 2023. 159 p.

Riley RH, Townsend CR, Niyogi DK, Arbuckle CA, Peacock KA. (2003) Headwater stream response to grassland agricultural development in New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 37: 389–403.

Ryder G, Tocher M. (2020) Review of values, freshwater restoration programmes and research needs within the Taieri Catchment. Report prepared by Ryder Consulting for the Department of Conservation. Department of Conservation, Dunedin. 144 p.

Snelder T, Larned S, Whitehead A. (2021) Guidance for the analysis of temporal trends in environmental data. NIWA Client Report 2021017WN prepared for Horizons Regional Council and MBIE Envirolink.

Soller JA, Schoen ME, Bertrand T, Ravenscroft JE, Ashbolt NJ. (2011) Estimated human health risks from exposure to recreational waters impacted by human and non-human sources of faecal contamination. *Water Research*, 44 (16) 4,674–4,691.

Thompson RM, Townsend CR. (1999) The effect of seasonal variation on the community structure and food-web attributes of two streams : implications for food-web science. *Oikos*, 97(1) 75–88.

Townsend CR, Arbuckle CJ, Crowl TA, Scarsbrook MR. (1997a) The relationship between land use and physicochemistry, food resources and macroinvertebrate communities in tributaries of the Taieri River, New Zealand: A hierarchically scaled approach. *Freshwater Biology* 37, 177–191.

Townsend CR, Scarsbrook MR, Doledec S. (1997b) The intermediate disturbance hypothesis, refugia and biodiversity in streams. *Limnology and Oceanography*, 42: 938–949.

Uytendaal A, Ozanne R. (2018) State of the environment surface water quality in Otago: 2006 to 2017. Otago Regional Council science report. 218 p.

Whitehead A, Depree C, Quinn J. (2019) Seasonal and temporal variation in water quality in New Zealand rivers and lakes. NIWA Client Report No. 2019024CH prepared for the Ministry for the Environment. 77 p.